

***Site Characterization and First Quarter 2011
Groundwater Monitoring Report***

***North Pole Refinery
North Pole, Alaska
DEC File Number: 100.38.090***

***Prepared for
Flint Hills Resources Alaska, LLC***

May 2011

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North Pole Refinery
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May 2011

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List of Abbreviations and Acronyms

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ADHSS	Alaska Department of Health and Social Services
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation & Public Facilities
AFCEE	Air Force Center for Engineering and the Environment
ARCADIS	ARCADIS, US, Inc.
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
Barr	Barr Engineering Company
BGS	below ground surface
BOD	biological oxygen demand
BTEX	benzene, toluene, ethylbenzene, and xylenes
CA	tank farm containment area
CCV	continuing calibration verification
COC	contaminants of concern
COD	chemical oxygen demand
COI	contaminants of interest
COPC	contaminants of potential concern

COV	coefficient of variation
CSM	Conceptual Site Model
CSP	Contaminated Sites Program
CU	crude unit
DEM	digital elevation model
DNAPL	dense nonaqueous-phase liquid
DRO	diesel range organic compounds
DVD	digital video disc
EB	equipment blank
EDD	electronic data deliverable
ESI	Environmental Standards, Inc.
EU	extraction unit
FHRA	Flint Hills Resources Alaska, LLC
FNSB	Fairbanks North Star Borough
ft/day	feet per day
ft MSL	feet above mean sea level
g	grams
GAC	granular activated carbon
gpm	gallon per minute
GPR	ground penetrating radar
GRO	gasoline range organic compounds
GVEA	Golden Valley Electrical Association
Homestead	Homestead Drilling Company
in/yr	inches per year
IRAP	Interim Removal Action Plan
IRIS	Integrated Risk Information System
ITRC	the Interstate Technology & Regulatory Council
LCM	LNAPL Conceptual Model
LCS	laboratory control sample
LCSD	LCD duplicate
LIF	laser-induced fluorescence
LNAPL	light nonaqueous-phase liquid
LOQ	limit of quantitation
L/kg	liters per kilogram
MAROS	Monitoring and Remediation Optimization System

MAPCO	MAPCO Petroleum, Inc.
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
MS	matrix spike
MSD	MS duplicate
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MNA	monitored natural attenuation
NAPL	nonaqueous-phase liquid
NPR	North Pole Refinery
ORP	oxidation reduction potential
PAH	polynuclear aromatic hydrocarbon
PCA	principal component analysis
PFD	Process Flow Diagram
PID	photoionization detector
POE	Point-of-Entry
ppb	parts per billion
ppm	parts per million
PQL	practical quantitation limit
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
Reiss	Reiss Remediation, LLC
ROW	right-of-way
RPD	relative percent difference
RRO	residual range organic compounds
RSL	regional screening level
SAP	Sampling and Analysis Plan
SC/CAP	Site Characterization Report and Corrective Action Plan
SCL	soil cleanup level
SCWP	Site Characterization Work Plan
SGS	SGS Environmental Services, Inc.
SIR	Supervisor Incident Report
SOP	standard operating procedure
SPAR	Division of Spill Prevention and Response

SVOC	semivolatile organic compound
SWI	Shannon & Wilson, Inc.
TAH	total aromatic hydrocarbons
TaqH	total aqueous hydrocarbons
TCP	traffic control plan
The City	The City of North Pole, Alaska
TKN	total kjeldahl nitrogen
TMB	trimethylbenzene
TOC	total organic carbon
TPT	Technical Project Team
USCOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
VOC	volatile organic compound
WELTS	Well Log Tracking System
WQA	Water Quality Association
WWTP	wastewater treatment plant
yd ³	cubic yards

Executive Summary

This *Site Characterization and First Quarter Groundwater Monitoring Report* (Report) has been prepared to provide a description of site characterization tasks that have been completed thus far and the results of those tasks for the Flint Hills Resources Alaska, LLC (FHRA) North Pole Refinery (NPR), located in North Pole, Alaska. As agreed upon with the Alaska Department of Environmental Conservation (ADEC), it also includes the results of groundwater monitoring completed during the first quarter of 2011. The tasks were proposed and described in the *Site Characterization Work Plan* (SCWP). Specific objectives of the tasks proposed in the SCWP included the following:

- Update the site Contaminants of Potential Concern (COPC).
- Identify the historical source(s) of sulfolane and the potential for ongoing releases.
- Improve the understanding of the onsite physical setting and gain an understanding of the offsite physical setting, including the geology, hydrogeology, permafrost, and groundwater geochemistry.
- Characterize the nature and extent of soil impacts at NPR once the COPCs are updated, the spill locations are understood, and sulfolane use is understood.
- Characterize the nature and occurrence of LNAPL at NPR.
- Improve the understanding of petroleum constituents in groundwater at NPR.
- Complete the delineation of sulfolane in groundwater downgradient of NPR.
- Evaluate the potential for natural attenuation of sulfolane in groundwater.
- Determine if sulfolane is present in water in the North and South Gravel Pits at NPR.
- Update the CSM.
- Evaluate the migration of sulfolane in groundwater through analytical modeling.
- Monitor the effectiveness of the corrective measures proposed in the IRAP.

As FHRA has indicated during TPT meetings and in other communications with ADEC, several of the tasks proposed in the SCWP are ongoing. In addition, many of the new delineation wells have not been sampled an adequate number of times to establish trends. Therefore, an addendum to this report will be prepared once these goals are completed. Details of continuing and proposed expanded data-gathering tasks are included in this submittal.

ES-1 Site Characterization Tasks

ES-1.1 Evaluation of Potential Sources and Potential for Ongoing Releases

Potential sources of contamination and known spill events and historical releases were evaluated to gain an understanding of where corrective action may be is needed, determine the source of groundwater contamination that has migrated beyond the original release location(s), and determine if the release mechanisms are still actively contributing contaminants to the environment. The task was completed with the consideration of process knowledge and facility documentation and operating history.

ES-1.2 Evaluation of Potential Contaminants of Concern

Potential contaminants of concern for NPR were evaluated to determine if there are any additional constituents that should be evaluated in the CSM, if any constituents should be added to or removed from the current list of monitoring parameters, and if these parameters potentially need to be addressed during ongoing and future corrective action.

ES-1.3 Characterize Physical Setting

Understanding the physical setting is critical to determine how contaminants migrate in the subsurface environment. Data needs that exist in the understanding of the geology, hydrogeology, and permafrost occurrence are being filled through the installation of monitoring wells and their associated soil borings, and by monitoring conditions in those wells. Characterization of the Physical setting was completed primarily though the installation of numerous onsite and offsite monitoring wells, monitoring of groundwater elevations, a geophysical survey, and analyzing groundwater samples for geochemical parameters.

ES-1.4 Characterize Soil Impacts

Historically, limited investigations of potential soil impacts at NPR have been completed due to the fact that the water table is very shallow, and the stability of the benzene and LNAPL plumes indicated the pump and treat remediation system was capturing the plumes, including contaminants that could be leaching from potentially impacted vadose zone soils. Soil results from site

characterization, the laboratory drain investigation a sump investigation, and previous SWI investigations were reviewed. A comprehensive onsite soil investigation was not completed during the winter of 2010/2011 due to the inherent difficulties in collecting, field screening, and handling soil samples during extreme cold weather. FHRA is planning to complete the onsite investigation during the summer of 2011.

ES-1.5 Characterize NAPL

The NAPL characterization results are being used to confirm the stability of the LNAPL plume and monitor the effectiveness of the interim removal actions. As these are long-term goals, several of the proposed tasks are ongoing and will continue as groundwater monitoring and IRAP implementation continues. LNAPL characterization has begun by expanding the LNAPL monitoring network, installation of four new observation wells, bail-down LNAPL recovery testing, smear zone chemical profiling, LNAPL sampling and analysis. Deep monitoring well data have been used to assess the potential for DNAPL.

ES-1.6 Characterize Groundwater Impacts

Characterization of the dissolved-phase plumes is being completed by collecting and analyzing groundwater sampling from monitoring wells. Depending on the well location, groundwater samples are analyzed for BTEX; 1,2,4-TMB; sulfolane; and/or natural attenuation parameters.

Evaluation of the resulting data for trends and responses to groundwater elevation fluctuations has started and will be continued as more data are collected. Evaluation of data has also begun with respect to natural attenuation of sulfolane, the results of which will eventually be used as part of a feasibility study of the offsite plume. Groundwater data will eventually be used as a tool to monitor the effectiveness of the IRAP, and then final corrective actions.

A door-to-door survey was conducted in search areas located downgradient of NPR in order to identify private water supply wells, and if possible, sample the wells for sulfolane.

An Offsite Feasibility Study will be completed to evaluate potential remedies, including monitored natural attenuation (MNA), to address sulfolane-impacted groundwater occurring beyond the limits of NPR. Groundwater sampling at several offsite monitoring wells will, over time, provide the information necessary to evaluate the potential for natural attenuation of dissolved sulfolane.

A preliminary analysis of the temporal variability in sulfolane, BTEX, and 1,2,4-TMB groundwater concentrations in the area of NPR was undertaken using the Monitoring and Remediation Optimization System (MAROS) and a computer program developed by SWI.

ES-1.7 Gravel Pit and Surface Water Sampling and Analysis

Surface water samples were collected from the onsite north and south gravel pits. An additional surface water sample was collected from Badger Slough, north of the extension of Garnet Drive

ES-2 Results and Findings

ES-2.1 Sources and Release Mechanisms

Potential sources of contamination include product storage tanks; USTs; product distribution systems including the truck-loading racks and railcar-loading areas; the process areas including CUs #1, #2, and #3 and the extraction unit (EU); the wastewater system, including the wastewater lagoons, sumps and drain systems; drum storage areas; waste piles; and septic systems. Of these areas, sulfolane was present or potentially present in the sulfolane storage tank (Tank 194); Tanks 192, 195, and 196; the railcar and new truck-loading rack, the EU, and the wastewater lagoons, sumps and drain systems. Due to the large number of historical releases and a lack of information regarding specific cleanup actions and soil sampling a soil investigation will be performed in 2011.

Evaluation of LNAPL and dissolved-phase data, together with FHRA's Mechanical Integrity & Inspection Program and its Active Awareness Program will provide data regarding potential ongoing releases.

ES-2.2 Contaminants of Concern

The COPCs identified at the site, are those COIs that were detected in site media and exceeded conservative ADEC screening levels, COIs not detected in site media but their PQLs exceeded ADEC screening levels, and COIs identified by the refinery laboratory as "ingredients" that could have been released and, therefore, are considered potential COPCs. Constituents without available USEPA toxicity values, with the exception of sulfolane, and metals detected in site media at concentrations within the range of site-specific background concentrations were not selected as COPCs.

ES-2.3 Physical Setting

The geology of the area is dominated by a thick sequence of unconsolidated alluvial deposits. Up to 10 feet of silty deposits overlay a thick sequence of alluvial sand and gravel.

Permafrost has been encountered at depths of 3 feet to 150 in the vicinity of NPR. The bottom of permafrost ranged from 14 to 245 feet BGS at private wells and the thickness of permafrost layer was reported to range from five feet to 232 feet.

The aquifer beneath the alluvial plain between the Tanana and Chena Rivers generally consists of highly-transmissive sands and gravels under water table conditions. Hydraulic conductivities of the aquifer materials range from 1.1 to 2,400 feet per day (ft/day). The water table at NPR and offsite is shallow, typically occurring within 15 feet of the ground surface. The water table decreases in elevation to the northwest, mimicking the gradually decreasing elevation of the ground surface. Limited onsite well data indicate that the water table has fluctuated up to four feet since 2007. Preliminary data indicate an upward vertical gradient, although the data spans a short period of time in the winter.

ES-2.4 Soil Impacts

Evidence of soil impacts have been observed historically and recently at NPR. The data are from widely scattered locations across NPR, and many of the samples were collected near the water table, and may have been influence by contaminants migrating in groundwater. Therefore, soil quality remains a data need and will be addressed during the upcoming soil investigation described in Section 9.0.

ES-2.5 LNAPL

LNAPL can continue to act as a source of dissolved-phase contaminants and, as such, LNAPL is a primary target of ongoing and future corrective action. Thus far, LNAPL has been observed in the same areas it was observed prior to site characterization, and also two newly installed wells, O-2 and MW-176. Historical data indicate that LNAPL thicknesses generally increase as the water table elevation decreases

Preliminary bail-down data indicate that the recoverability of LNAPL was generally good, with the exception of S-44. Results of this bail-down testing, as well as future bail-down testing, will be used to compute LNAPL transmissivity for comparison to ITRC benchmark values to evaluate LNAPL recoverability.

Smear zone LNAPL is not apparent in the vicinity of well O-1, O-3, and O-4, but does appear to be present at O-2.

Only the LNAPL collected from MW-138 was found to contain sulfolane, an indication that NAPL may not be a significant contributor to sulfolane in groundwater.

Specific details regarding scope and schedule of the continuing LNAPL investigation are presented in Section 8.0.

Deep monitoring well data do not indicate the presence of a DNAPL layer. DNAPL would not be expected to be present as DNAPL because of its miscibility with water.

ES-2.6 Groundwater Impacts

BTEX & 1,2,4-TMB

Groundwater impacts have been, and continue to be, characterized through the analysis of groundwater samples collected from onsite and offsite monitoring wells. The 2010 and 2011 5-µg/L footprints appear to be similar to the 2002 footprint. Dissolved-phase toluene, ethylbenzene, xylenes, and 1,2,4-trimethylbenzene (TMB) appear to occur within the footprint of the benzene plume thus far.

Statistical trend analysis indicates nondetects, decreasing trends, probably decreasing, or stable trends were indicated at most wells in the BTEX network.

Sulfolane

The sulfolane plume is present at the water table under CUs #1 and #2 and the tank farms, extending north-northwesterly (downgradient) offsite from NPR. The highest concentrations were reported at onsite wells) near Lagoon B and downgradient of CU #2.

Sulfolane is present in groundwater at depths of 10 to 55 feet below the water table. Onsite, the plume is present below the tank farms, but apparently not below CU #1 or CU #2. The plume extends north-northwesterly (downgradient) offsite from NPR, in a manner similar to the water table plume.

Sulfolane has been detected in samples collected from wells screened 55 to 90 feet below the water table. The upgradient end of the plume appears to be located near the former truck-loading rack, and the plume extends north-northwesterly (downgradient) offsite from NPR. The permafrost may be limiting lateral migration of the plume at this depth.

Sulfolane has not been detected in samples collected from wells screened between 90 and 160 feet below the water table.

For wells at which sufficient data exists to complete a trend analysis, a stable, decreasing or probably decreasing, trend is indicated.

ES-2.7 MNA Evaluation

Preliminary data may be consistent with aerobic sulfonate. As ongoing MNA data are collected, they will be evaluated for trends in the MNA parameters along the flow path, with depth and with time. When sufficient data have been collected, the Mann-Kendall trend test will be applied to the data to discern increasing or decreasing trends in the data with distance and time.

The conclusion isotherm testing is that the degree of sulfonate adsorption to aquifer sediment is anticipated to be similar to what has been published in the literature for other sites. As ongoing data collection and evaluation of monitored natural attenuation proceeds, the distribution coefficients estimated from this work will be used to estimate the mass of sulfonate adsorbed to sediment, and account for that mass when assessing MNA progress.

ES-2.8 Geochemistry Evaluation

While some geochemical differences can be observed between sub and suprapermafrost waters, these differences are subtle. The subtlety of these differences, along with the small number of samples, limits the conclusions that can be drawn from the geochemical analysis. While the hypothesis tested by this work cannot be accepted based on these results, it cannot currently be rejected in favor of another, better supported hypothesis. Additional work will be completed with the aim to provide a more conclusive explanation for the presence of sulfonate in the subpermafrost wells.

ES-2.9 Gravel Pit and Surface Water Quality

The laboratory reported that sulfonate was not detected above its LOQ in either of the gravel pit samples the sample collected from Badger Slough.

ES-2.10 Updated Conceptual Site Model

The CSM for NPR has been updated.

Onsite Exposure Pathways

Potential current and future onsite receptors may be exposed to constituents in surface and subsurface soils by direct contact, and groundwater by direct contact via soil excavations to the water table. Some COPCs identified for the site have the potential to volatilize from subsurface soil and/or

groundwater into soil gas, outdoor air and indoor air. Potential exposure pathways at the site may include volatilization of COPCs to outdoor air and/or indoor air.

Offsite Exposure Pathways

The only known current offsite COPC is dissolved-phase sulfolane. Although dissolved-phase petroleum constituents are present onsite, the plume is undergoing ongoing active remediation, and migration appears to be controlled. Because sulfolane is not volatile and is not readily absorbable by skin, the only exposure route evaluated for potential offsite receptors is ingestion.

Ingestion of groundwater is a potentially complete pathway for the potential offsite receptors.

Ingestion of surface water is a potentially complete exposure pathway for recreational users because surface water samples within the footprint of the dissolved-phase plume have not been collected.

Ingestion of wild foods is a complete exposure pathway for potential offsite residents. “Wild” foods are not expected to be impacted by COPCs from the site due to the sizeable depth to groundwater and lack of offsite soil impact. However, farmed or home-grown plants irrigated with water potentially impacted by sulfolane may accumulate concentrations of this COPC. Thus, ingestion of farmed foods is a potentially complete exposure pathway for current and future offsite residents.

Ecological CSM

An ecological CSM to determine if COC impacts onsite or offsite will come in contact with ecological receptors is in progress. Per discussions with ADEC, the ecological CSM will be developed and submitted under separate cover by June 15, 2011.

ES-2.11 Risk Assessment

A risk assessment will be prepared to evaluate the risk posed by environmental conditions at the site and to develop alternate cleanup levels as appropriate. However, based on the data collected as part of the site characterization effort, some data needs are still present that are critical to a complete understanding of the conceptual site model. Section 8.0 presents recommendations to address these data needs during the 2011 field season. FHRA will meet with ADEC in June 2011 for a risk assessment Scoping Meeting.

ES-3 Groundwater Flow and Transport Modeling

A groundwater model of the Tanana Valley in the vicinity of the NPR has been constructed for the purpose of simulating the fate and transport of sulfolane from the site. The modeling goals were to

obtain an acceptable match between the simulated versus observed water levels and sulfolane concentrations so the model can be used as a tool for assessing potential remediation options. The observed sulfolane concentrations were derived from FHRA monitoring wells. Recently received residential well sulfolane concentrations will be incorporated into future modeling efforts. The model has been developed in accordance with ADEC guidelines for fate and transport modeling. Once site characterization is completed, the data will be used to update the input files for the model.

ES-4 Status Update on Cleanup Actions

ES-4.1 Onsite

Operation of the groundwater pump and treat system currently involves groundwater recovery from four existing and a fifth new recovery well installed as part of the IRAP implementation. The objective of the recovery well operation is to provide capture of the shallow dissolved-phase contaminant plume. Recovered groundwater is treated onsite prior to discharge. Groundwater capture was increased significantly in 2010 and FHRA is continuing efforts to optimize the groundwater recovery of the existing remediation system in 2011.

FHRA continues to remove LNAPL from recovery wells and monitoring wells through active product pumping systems, passive product recovery canisters, periodic removal with a vacuum truck, and collection in the coalescer installed ahead of the air stripper. FHRA is in the process of installing seven additional product recovery systems.

From 1986 to current, over 386,000 gallons of LNAPL has been recovered at the North Pole refinery. As expected, the annual product recovery volume has generally decreased as remediation has progressed and the volume of recoverable LNAPL has decreased.

FHRA has implemented interim corrective actions, as proposed in the IRAP, with the purpose of optimizing the existing remediation system to aggressively address, to the extent practical, LNAPL and sulfolane-contaminated groundwater on the refinery property. After a period of full-scale operation with the improvements made as part of the IRAP, the results will be evaluated as part of a feasibility study to determine if additional corrective actions are necessary to meet the objectives of LNAPL recovery and source area plume capture and treatment. The feasibility study results and additional corrective actions, if needed, will be included as part of the final remedy in the *Corrective Action Cleanup Plan*.

At the time of submittal of this report, FHRA is in the final stages of completing the interim corrective actions described in the IRAP. FHRA is in the process of completing construction of the GAC filtration system and active operation is scheduled for early June.

ES-4.2 Offsite

In accordance with Section 6.8 of the SCWP, FHRA is in the process of collecting data necessary to complete a feasibility study to evaluate potential alternatives, including MNA, to determine how groundwater impacts beyond the limits of NPR will be addressed. An additional element of the feasibility study includes further completion of flow and transport modeling efforts. The fate and transport model results, along with the conceptual site model and risk exposure pathway evaluation will be the basis for evaluating future remedial alternatives including MNA.

In the interim, to address potential drinking water risks associated with offsite dissolved-phase groundwater contamination, FHRA has replaced the City of North Pole's existing municipal wells; and provided alternate water supplies to residents whose private wells have exhibited detections of sulfolane.

FHRA has conducted a feasibility study for in-home treatment which indicated a point-of-entry (POE) GAC filtration system as the best technology for sulfolane removal. FHRA has assembled full-scale POE treatment systems and conducted additional testing to evaluate effectiveness during residential usage. To provide assurances to residents who utilize a POE treatment system, FHRA requested the Water Quality Association (WQA) to provide a third-party independent review as part of their Gold Seal Certification Program. WQA has completed their review of the pilot-testing results and has provided certification of the treatment system effectiveness.

ES-5 Recommendations

Preliminary conclusions have been drawn from the data gathered to date; however, in some cases, the completion of the site characterization tasks are required to confirm these conclusions. Tasks to be completed and new tasks that are needed to fill data needs are described below.

ES-5.1 Soil Investigation

FHRA is proposing to complete an onsite, grid-based soil investigation. The gridlines will be spaced at 100-foot intervals and borings will be placed at the intersections of the gridlines to the extent practical, within accessible areas of the property. The investigation will serve to delineate silty layers in the shallow subsurface, investigate known and potential releases by characterizing soil impacts at boring locations; confirm the presence or absence of sulfolane in the release locations;

determine the presence of COPCs in soils; and provide additional soil samples for smear zone chemical profiling to fill data needs for the LNAPL conceptual model. Details of the investigation will be provided in a work plan.

ES-5.2 Groundwater Elevation Monitoring

Groundwater elevation monitoring has begun, and will continue not only as site characterization continues, but also as part of any future long-term groundwater monitoring. To date, a full annual cycle, necessary to gauge seasonal variations in gradient and flow direction, has yet to be collected from the expanded monitoring network, including the well nests. These data will be used to further characterize horizontal and vertical gradients, and will be important for the ongoing and future onsite cleanup actions and the feasibility study. All new wells installed since submittal of the SCWP, and to be installed during 2011, will be added to the monitoring network. .

ES-5.3 LNAPL Investigation

LNAPL monitoring has begun, and will continue through site characterization and long-term groundwater monitoring. To date, a full annual cycle has yet to be collected from the expanded LNAPL monitoring network. These data are important to understand the LNAPL occurrence and recoverability.

Due to the presence of LNAPL in well O-2, a product recovery system will be installed in the well to provide continuous removal of product and to prevent potential migration of product in the area of this well. FHRA proposes to install an additional observation well approximately 150 feet northwest of O-2 to confirm product recovery from this well is effective.

Bail-down testing indicated potential good recoverability of LNAPL for most of the wells tested to date. Additional bail-down testing is proposed to provide a more comprehensive indication of recoverability across the site, along with calculations of LNAPL transmissivity from the resulting bail-down data.

LNAPL occurrence and recoverability may be influenced by geologic features such as silty layers in the vadose zone, the capillary fringe, and the shallow saturated zone. The continuous soil sampling to be completed as part of the shallow soil investigation, will provide the data necessary to map these potential fine-grained layers.

The limited number of smear zone samples provided an initial indication that LNAPL impacts are generally shallow. Additional smear-zone sampling during the soil investigation will provide more data across the site.

Additional LNAPL composition sampling is proposed to provide a more comprehensive understanding of LNAPL characteristics across the site and provide input for further development of the LNAPL conceptual model.

ES-5.4 Monitoring BTEX & 1,2,4-TMB in Groundwater

The benzene, toluene, ethylbenzene, and xylenes plumes are relatively well defined and statistical analyses indicate stable or decreasing trends at most locations. Insufficient data have been collected to establish 1,2,4-TMB trends at any locations, and BTEX trends at locations recently added to the monitoring network. Therefore, FHRA will continue the monitoring proposed in the SCWP. Data evaluation and comparison to groundwater elevation results will continue in accordance with the SCWP.

ES-5.5 Monitoring Sulfolane in Groundwater

Horizontal and vertical delineation of the sulfolane plume has progressed; however, a few data needs exist along the plume edges. On March 8, 2011, FHRA proposed to install fourteen additional monitoring wells to progress the understanding of the sulfolane plume. Six of these wells will be installed across the water table, and eight wells will be installed to a depth of approximately 50 feet BGS.

Statistical analyses indicate stable or decreasing trends at most locations for which sufficient data are available to complete the analysis. As is the case with BTEX and 1,2,4-TMB monitoring, sulfolane monitoring has just started for many of the locations in the expanded monitoring network and trends have yet to be established, especially as related to fluctuations in groundwater elevations and gradients. FHRA will, therefore, continue the sulfolane groundwater monitoring program established in the SCWP to monitor plume stability. Data evaluation and comparison to groundwater elevation results will continue in accordance with the SCWP.

ES-5.6 Monitored Natural Attenuation

To date, one round of MNA data have been collected. MNA sampling and analysis will continue as proposed in the SCWP and in support of an upcoming Offsite Feasibility Study. As ongoing MNA data are collected, they will be evaluated for trends in the MNA parameters along the flow path, with depth and with time. When sufficient data have been collected, the Mann-Kendall trend test will be

applied to the data to discern increasing or decreasing trends in the data with distance and time (subject to any constraints of the method relative to seasonal variability).

The degree of sulfolane adsorption to aquifer sediment is anticipated to be similar to what has been published in the literature for other sites. As ongoing data collection and evaluation of MNA proceeds, the distribution coefficients estimated from this work will be used to estimate the mass of sulfolane adsorbed to sediment, and account for that mass when assessing MNA progress.

ES-5.7 Evaluation of Subpermafrost Private Wells

The results of the geochemical sampling and analysis conducted on sub and suprapermafrost wells did not support the development of conclusions regarding the source of subpermafrost sulfolane impacts. Additional sampling and analysis will be completed to provide additional information for development of a conclusive answer regarding the source of subpermafrost sulfolane. Plans for additional sampling and new analytical methods/approaches will be detailed in a future work plan.

ES-5.8 Ecological CSM

The ecological CSM is in progress. Results will be used to determine if COC impacts onsite or offsite will come in contact with ecological receptors. Per discussions with ADEC, the ecological CSM will be developed and submitted under separate cover by June 15, 2011.

ES-5.9 Flow and Transport Model

Once site characterization is completed, the data will be used to update the input files for the groundwater model. The model will be updated within 90 days of the completion of site characterization tasks.

ES-5.10 Schedule

Site characterization tasks are still ongoing, even with the preparation of this document, and will continue through 2011. The additional tasks listed above will be completed concurrently with the ongoing tasks, with the goal of completion in 2011.

ES-5.11 Reporting

Results of the continuing site characterization tasks and the new tasks proposed here will be presented in a Site Characterization Addendum. Site characterization is anticipated to be completed by the end of 2011.

As agreed upon with ADEC, FHRA will report the results of groundwater monitoring on a quarterly basis. Each quarterly report will be submitted at the end of the month that follows the end of the preceding quarter (e.g., the second quarter report will be submitted by July 31st).

The TPT meetings and the Site Characterization and Remediation subgroup meetings will also be used as opportunities to provide updates, propose changes to work, and discuss results.

1.0 Introduction

This *Site Characterization and First Quarter Groundwater Monitoring Report* (Report) has been prepared to provide a description of site characterization tasks that have been completed thus far and the results of those tasks for the Flint Hills Resources Alaska, LLC (FHRA) North Pole Refinery (NPR), located in North Pole, Alaska. The tasks were proposed and described in the *Site Characterization Work Plan* (SCWP) in order to update the Conceptual Site Model (CSM), as requested by the Alaska Department of Environmental Conservation (ADEC). A *Site Characterization Report and Corrective Action Plan*, Williams Alaska Petroleum, Inc., North Pole Refinery (SC/CAP) for NPR was previously prepared by Shannon and Wilson, Inc. (SWI), and submitted to ADEC in June 2002. As indicated by ADEC, the compound sulfolane, a solvent used at the refinery that had been detected in site groundwater samples, was not included in the SC/CAP at that time because it was not a regulated substance. ADEC approved the SC/CAP in January 2006 and included a new requirement that sulfolane would be regulated with a groundwater cleanup goal of 350 micrograms per liter ($\mu\text{g/L}$) at NPR.

In October 2009, sulfolane was detected in both private and public drinking water wells near NPR. Following notification to ADEC, FHRA immediately began simultaneous efforts to delineate the extent of the sulfolane plume, test the drinking water supplies of those living in the vicinity of NPR, and provide alternative drinking water supplies to those with impacted wells.

In a letter to FHRA dated March 3, 2010, ADEC indicated that, based on new information related to sulfolane, the January 2002 SC/CAP was no longer sufficiently protective and directed FHRA to prepare a SCWP to address these new conditions. In the letter, ADEC stated its intent to consider 25 parts per billion (ppb) as an interim cleanup level for sulfolane in groundwater. ADEC's letter directed FHRA to submit a *Site Characterization Report* and *Revised Corrective Action Plan* following completion of the site characterization.

ADEC also directed FHRA to prepare an *Interim Removal Action Plan* (IRAP) to address the light nonaqueous-phase liquid (LNAPL) and sulfolane-contaminated groundwater present at NPR. A status update on cleanup actions is included in this Report. This update does not take the place of the *Corrective Action Cleanup Plan*, which will include a complete evaluation of interim corrective actions. Additional onsite corrective actions, if necessary, will be evaluated for determination of the final remedy in the *Corrective Action Cleanup Plan*. A *Corrective Action Cleanup Report* will be submitted following a period of active operation to document the final implementation and to

evaluate and demonstrate effectiveness. In addition, an Offsite Feasibility Study will be completed to evaluate potential remedies, including natural attenuation, to address sulfolane-impacted groundwater occurring outside the limits of the North Pole Refinery property. A technical memorandum will be prepared and submitted for ADEC approval subsequent to this report to better define the ongoing data collection activities to be completed in support of the future offsite feasibility study effort.

A draft SCWP and a draft IRAP were submitted to ADEC on July 23, 2010. ADEC provided preliminary approval to begin work described in the documents on August 7, 2010. The final SCWP and IRAP were submitted on September 20, 2010. As of the submittal date of this report, ADEC has not provided written comments on, or approval of, these submittals.

On December 7, 2010, ADEC requested FHRA to alter its monthly groundwater reporting format. As the monthly reports included a large amount of information not needed for submittal on a monthly basis, the reports were no longer efficient for FHRA to prepare or ADEC to review, and the number of monitoring locations had increased substantially since initiation of the monthly format. At the December 14, 2010, Technical Project Team (TPT) meeting, FHRA proposed a quarterly reporting frequency. FHRA also proposed an outline of the report, which included the results of the interim groundwater monitoring program proposed in the SCWP and updates on remediation progress and system upgrades proposed in the IRAP. At the February 16, 2011 TPT Meeting, ADEC recommended that the *First Quarter 2011 Groundwater Monitoring Report* be combined with this Site Characterization Report, to be submitted by May 31, 2011. Subsequent quarterly reports would be submitted by the end of the month following the end of each quarter.

This report, therefore, includes data gathered thus far during site characterization, results of groundwater monitoring completed during the first quarter of 2011, and an update on onsite remediation progress.

1.1 Project Objectives

The SCWP identified data needs in the understanding of environmental conditions at NPR, and proposed tasks to fill those data needs and update the CSM. Specific objectives of the tasks proposed in the SCWP included the following:

- Update the site Contaminants of Potential Concern (COPC).
- Identify the historic source(s) of sulfolane and the potential for ongoing releases.

- Improve the understanding of the onsite physical setting and gain an understanding of the offsite physical setting, including the geology, hydrogeology, permafrost, and groundwater geochemistry.
- Characterize the nature and extent of soil impacts at NPR once the COPCs are updated, the spill locations are understood, and sulfolane use is understood.
- Characterize the nature and occurrence of LNAPL at NPR.
- Improve the understanding of petroleum constituents in groundwater at NPR.
- Complete the delineation of sulfolane in groundwater downgradient of NPR.
- Evaluate the potential for natural attenuation of sulfolane in groundwater downgradient of NPR.
- Characterize water quality with respect to sulfolane in the North and South Gravel Pits at NPR.
- Update the CSM.
- Evaluate the migration of sulfolane in groundwater through analytical modeling.
- Monitor the effectiveness of the corrective measures proposed in the IRAP.

As FHRA has indicated during TPT meetings and in other communications with ADEC, several of the tasks proposed in the SCWP have yet to be completed. In addition, many of the new delineation wells have not been sampled an adequate number of times to establish trends, and several new wells have been proposed. Also, the expanded groundwater monitoring program proposed in the SCWP has not been established long enough to capture all seasonal trends. Therefore, an addendum to this report will be prepared once these goals are completed. Any tasks proposed in the SCWP that are not discussed in this submittal will be addressed in the Addendum.

A review of historical data and data gathered during site characterization has improved FHRA's understanding of this complex site. This has allowed FHRA to focus some of the SCWP tasks such as the natural attenuation evaluation and the onsite LNAPL evaluation, and to make data gathering in support of these evaluations more robust. Details of these proposed expanded data- gathering tasks are included in Section 8.0 – Recommendations.

1.2 Summary of Site History

NPR is a petroleum refinery that receives its crude oil feedstock from the Trans-Alaska Pipeline. The property was developed as the refinery was constructed in the mid-1970s. Operations began in 1977. In 1982, then owner MAPCO began recovering LNAPL from the subsurface. Sulfolane use at NPR began in 1985 when Crude Unit (CU) #2 was constructed. In 1988, air strippers were installed to treat impacted groundwater that was pumped from recovery wells. The facility was acquired by Williams Alaska Petroleum, Inc. in 1998. CU #3 was constructed in 1998. In 2001, Williams Alaska Petroleum, Inc. first reported to ADEC that sulfolane was identified in groundwater samples; the 2002 SC/CAP did not include sulfolane. FHRA purchased NPR in 2004. The SC/CAP was approved by ADEC in 2006, stipulating a sulfolane cleanup goal for groundwater of 350 µg/L.

1.3 Property Description

NPR is located just outside the city limits of the City of North Pole (the City), Alaska. The City is located approximately 13 miles southeast of Fairbanks, Alaska, within Fairbanks North Star Borough (Figure 1). The address of NPR is 1100 H & H Lane, North Pole, Alaska 99705.

NPR is situated on a parcel that is approximately 240 acres in size and located in Section 16, Township 2 South, Range 2 East, Fairbanks Meridian. The latitude and longitude of the approximate center point of FHRA's property is 64.74 N and 147.35 W. The refinery, parcel boundaries, nearby roads and surrounding areas are shown on Figure 2 and the onsite features are shown on Figure 3, and also in Appendix A. No institutional controls (e.g., deed restrictions) are currently in place (Horst, 2010).

Flint Hills Resources Alaska, LLC is the current owner and operator of NPR. FHRA and Williams Alaska Petroleum, Inc. are currently in a legal dispute for purposes of determining responsible party status.

1.4 Report Organization

This report has been prepared in general accordance with *the Site Characterization Work Plan and Reporting Guidance for Investigation of Contaminated Sites* (ADEC, 2009). It is organized into the following sections.

Section 1 – Introduction: a description of the events that lead up to site characterization, a summary of the project objectives, a brief recap of site history and property description, and submittal organization.

Section 2 – Site Characterization Tasks: a description of the tasks and the methodology used to complete those tasks completed thus far during site characterization, including deviations from the SCWP. In addition to field work, tasks included the review of historical data and documents and, as such, this section replaces the “Field Work” section listed in the Elements of a Complete Characterization Report from the ADEC Guidance Documents (ADEC, 2009).

Section 3 – Results and Findings: a presentation of the data gathered thus far during site characterization, including the data that would have been presented in the *First Quarter 2011 Groundwater Monitoring Report* for NPR.

Section 4 – Groundwater Flow and Transport Modeling: a description of the groundwater model that has been constructed for the purpose of simulating the fate and transport of sulfolane from the site once site characterization is complete.

Section 5 – Status Update on Cleanup Actions: a description of the progress made thus far implementing the IRAP.

Section 6 – Quality Assurance/Quality Control: a description of the Quality Assurance/Quality Control (QA/QC) procedures that were followed to evaluate the quality of the analytical data, and the results of the evaluation.

Section 7 – Summary and Conclusions: a summary of the results thus far of site characterization and a description of preliminary conclusions drawn from them.

Section 8 – Recommendations: recommendations to complete site characterization.

This bound report includes paper copies of the text, tables, and figures. Appendices are provided as electronic files on the enclosed digital video disc (DVD). Paper copies of specific appendices are available upon request as practical.

2.0 Site Characterization Tasks

This section describes the methodologies used to complete the tasks that were proposed in the SCWP in order to meet the objectives listed in Section 1.1. The results are used to address data needs, improve understanding of existing data, and update the CSM.

The scope of each task was described in the SCWP, and any deviations from the scope, and the reasons for the deviations are described in the following sections. The tasks were completed following the procedures described in the Sampling and Analysis Plan (SAP), Appendix M of the SCWP, to the extent practical. The SAP was revised on December 28, 2010, to incorporate cold weather protocols and soil management protocols. Deviations from the SAP and the reasons for the deviations are described in the sections below.

2.1 Identify Sources and Release Mechanisms

The identification of source and release mechanisms is important to gain an understanding of where corrective action is needed, determine the source of groundwater contamination that has migrated beyond the original release location(s), and determine if the release mechanisms are still actively contributing contaminants to the environment. The task was completed with the consideration of process knowledge and facility documentation and operating history.

2.1.1 Locate Potential Sources of Contamination

Potential sources of contamination were determined by contacting FHRA staff and reviewing NPR files, including maps and process diagrams. Information was obtained regarding the locations of product storage tanks; underground storage tanks (USTs); product distribution systems including the truck-loading racks and railcar-loading areas; the wastewater flow path, including the wastewater lagoons, sumps and drain systems; drum storage areas; waste piles; and septic systems. Results of the review are presented in Section 3.1.1.

While it is known that dissolved-phase sulfolane is present in the groundwater at NPR, the mechanism through which it entered the environment was not previously understood. The SCWP noted that a release of pure sulfolane was known to have occurred at NPR, however, the volume was small (150 gallons). Other potential sources included releases of wastewater containing sulfolane and/or petroleum product containing sulfolane. Historical files and refinery process diagrams were reviewed to determine the areas of NPR in which sulfolane may have been present. The wastewater

flow paths have been documented due to the potential for wastewater to contain sulfolane. Results are presented in Section 3.1.1.

During a meeting with ADEC to discuss the SCWP in May 2010, a request was made to present the findings of a United States Environmental Protection Agency (USEPA) wastewater treatment plant inspection. FHRA is unaware of USEPA inspections of the NPR wastewater treatment plant.

2.1.2 Review Spill Events and Historical Releases

FHRA and ADEC files have been reviewed to evaluate known spill events and historical releases. The information gleaned from the review was used to update the contaminants of potential concern, identify release locations and volumes, and determine if adequate cleanup actions had occurred. Results of this review are discussed in Section 3.1.2.

Various spill reporting records have been maintained by facility operators during operation of the facility. The files were reviewed to obtain information regarding the release volumes and locations, and the cleanup actions performed in response to the releases. Historical records indicate, however, that substantial volumes of materials were released but not documented. During the period of FHRA's ownership, FHRA's policy has been to document all spills regardless of volume. FHRA is not in a position to verify the completeness or accuracy of records that were maintained prior to their ownership of NPR.

2.1.3 Evaluate Potential for Ongoing Release

A systematic evaluation of sumps was completed in 2010 in order to determine if the sumps were contributing contaminants to the subsurface. The results were presented in a letter report to ADEC in December 2010. Investigations completed at specific sumps are discussed in Sections 2.4.3. A map showing sump locations is included in Appendix A.

The sump investigation was part of FHRA's Mechanical Integrity & Inspection Program and Active Awareness program. FHRA staff provided details of these programs, as described in Section 3.1.3.

In addition to the inspection program, data gathered during ongoing site characterization, groundwater monitoring, and cleanup actions will be used as indicators for ongoing releases. Specific data include LNAPL occurrence trends (extent and thickness), LNAPL analyses (for potential identification of product released and for potential product age determination), and dissolved-phase contaminant trends.

2.1.4 Potential Offsite Sources

Due to the potential for residual sulfolane to be present in fuels, it is possible that sulfolane is present in the soils and groundwater at other petroleum release sites in the area. These other potential sources may interfere with the ongoing plume delineation work. SWI searched the ADEC contaminated sites database (http://www.dec.state.ak.us/spar/csp/db_search.htm) for sites that are listed as active, closed, or closed with institutional control. SWI's project files were searched for sites. The search area extended south and southeast from the NPR to the Tanana River and flood-control channel, and five miles from the NPR in the other directions. A regulatory report was previously obtained from an independent vendor in order to identify potential release sites in the immediate vicinity of NPR and the known plume. Results are discussed in Section 3.1.4.

2.2 Evaluate Potential Contaminants of Concern

In accordance with the SCWP, potential contaminants of concern for NPR were evaluated to determine if there are any additional constituents that should be evaluated in the CSM, if any constituents should be added to or removed from the current list of monitoring parameters, and if these parameters potentially need to be addressed during ongoing and future corrective action. The COPC list was developed by comparing reported spill events and other known historical releases to the list of potential constituents contained in the release. Releases that were not contained, remediated, or otherwise sampled to determine potential release to the environment may contain COPCs.

The constituents of potential concern for human health were identified in accordance with ADEC (2008a; 2008b; 2010) guidance. COPCs were identified from an initial list of potential constituents of interest (COIs), such as those that were likely used or spilled at the site. Site history, spill records, and previous site characterization studies were used to develop an initial list of COIs. Those COIs that have concentrations detected above the laboratory practical quantitation limit (PQL) that exceed ADEC screening levels, were considered COPCs and will be carried through the human health risk assessment process. In addition, for each COI the PQLs were also compared with screening levels, and those with PQLs that exceeded screening levels were also selected as COPCs.

An initial list of COIs in soil and groundwater was identified from the SWI (2000; 2001) contaminant characterization studies conducted for the North Pole Refinery in 2000 and 2001. The purpose of the characterization study conducted at the refinery in 2001 was to collect additional soil and groundwater data to address data needs from an earlier site investigation that was conducted in 2000. In general, for both media, the analytical methods used included those for gasoline range organics

(GRO), diesel range organics (DRO), residual range organics (RRO), benzene, toluene, ethylbenzene, xylenes (BTEX), selected metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and sulfolane (for groundwater only).

2.3 Characterize Physical Setting

As noted in the SCWP, a number of data needs existed in the understanding of the physical setting, including the geology, hydrogeology, and permafrost occurrence which are critical factors that determine how contaminants migrate in the subsurface environment. These needs are being filled through the installation of monitoring wells and their associated soil borings, and by monitoring groundwater conditions at existing and new wells. The following sections describe the techniques and procedures used to accomplish these tasks. Additional tasks, including a geophysical survey, are also described below.

2.3.1 Soil Boring and Well Installation

Numerous wells have been installed onsite at NPR and at offsite (Figure 4) locations since October 2009, primarily for the purpose of delineating the sulfolane plume, but also for delineating LNAPL onsite, and for monitoring the effects of the onsite remediation systems. Data currently being gathered will be used to evaluate the potential for natural attenuation of the plume as part of a future feasibility study.

The wells were installed in two phases. Phase 1 was completed from October 2009 to April 2010, prior to preparation of the SCWP. Phase 2 was completed from September 2010 to November 2010, following submittal of the SCWP and in accordance with the SCWP. Further information regarding well locations, depths, and purpose are presented in the sections that describe expansion of the LNAPL monitoring network (Section 2.5.1) and sulfolane monitoring network (Section 2.6.2). Well construction details are included in Table 1, and boring logs are provided in Appendix B.

New monitoring wells were named using an alpha numeric system (MW-###) and are numbered consecutively, generally in the order in which they were installed. An alphabetic suffix was added to well numbers to indicate relative well depth for wells installed in nests. An “A” suffix was used for the shallowest well in a nest. Typically, the shallowest well was screened within 10 feet of the water table, with the following exceptions:

- At MW-154A, installed in the vicinity of existing water table well MW-139, the screen is set approximately 60 feet below the water table.

- At MW-174A, installed in the vicinity of existing water table well MW-111, the screen is set approximately 40 feet below the water table.

A “B” suffix was used for the second well in a nest, installed deeper than the A well. B wells were usually completed 10 to 55 feet below the water table, with the following exceptions:

- At the MW-144, MW-154, MW-160, and MW-174 well nests, the second wells installed at each (MW-144B, MW-154B, MW-160B, and MW-174B, respectively) were screened 77 to 80 feet below the water table;
- At the MW-149 nest, the second well (MW-149B) was installed at the top of apparent permafrost, with the screen set approximately seven feet below the water table;
- At the MW-170 nest, the second well installed (MW-170B) was screened approximately 60 feet below the water table; and
- At the MW-172 and MW-173 well nests, the second wells (MW-172B and MW-173B, respectively) were screened approximately 138 feet below the water table.

The C wells were used for the deepest wells in nests, typically ranging from approximately 55 feet to 160 feet below the water table, with the following exceptions:

- At MW-151C, the screen is set approximately 46 feet below the water table.

Only one “D” well was installed, MW-170D, which was screened approximately 36 feet below the water table. This well was given a “D” designation since it was the fourth well installed at this nest, after the installation of deeper wells MW-170B and MW-170C, as described above.

No suffix was typically used for solitary wells (i.e., they were not nested with other wells). Many of these wells were screened within 10 feet of the water table, with the following exceptions:

- MW-175 and MW-177, which were screened at depths of approximately 76 to 80 feet below the water table. and
- MW-184 and MW-188, which were screened at depths of approximately 30 feet below the water table.

Several preexisting wells named without suffixes are also screened below the water table, including:

- MW-101, MW-102, MW-104, MW-105, screened 50 to 55 feet below the water table;
- MW-118 and MW-129, screened approximately 30 feet below the water table; and
- MW-125, MW-126, and MW127, screened 10 to 15 feet below the water table.

New observation wells were also named using an alpha numeric system (O-#) and are numbered consecutively, generally in the order in which they were installed. Since all observation wells are installed across the water table, no suffix is necessary. Observation wells were installed within NPR are typically used for monitoring groundwater elevations and LNAPL thickness.

2.3.1.1 Permits and Utilities

The SCWP proposed to locate utilities to the extent practical. To date, underground utilities have been located onsite and offsite in preparation for drilling activities related to site characterization.

Onsite wells were installed on NPR property. Offsite wells were installed either within The City or Alaska Department of Transportation & Public Facilities (ADOT&PF) right-of-way (ROW), or on Fairbanks North Star Borough (FNSB) property. A traffic control plan (TCP) was prepared and utilized as necessary for well installations within the ADOT&PF ROW. Temporary use licenses were obtained from FNSB for well installation on FNSB property. Additional permissions were obtained from private land owners as necessary.

For onsite wells, utilities were located with FHRA refinery personnel and FHRA subcontractor Ray's Electric. For the offsite wells, utilities were located at each well location and coordinated with The City, FNSB, or ADOT&PF to obtain permission for installing the wells.

As described in Section 8.1, a soil investigation will be completed as part of ongoing site characterization. During the investigation, utilities will be located across the site. Offsite utilities will continue to be located only for the purpose of clearing monitoring well drilling locations.

2.3.1.2 Drilling and Soil Sampling

Homestead Drilling Company (Homestead) of Fairbanks, Alaska, under the direction of SWI completed the drilling, sampling, and well installation using a truck-mounted drill rig and the hollow-stem-auger technique. The deeper borings (i.e., those greater than approximately 50 feet below the ground surface [BGS]) were installed with the aid of bentonite drilling mud to counteract heaving sands and provide lubrication for the augers. A SWI field representative was present during the work.

Soil samples were collected using a split-barrel sampler as specified in the SAP, in general accordance with ASTM International (ASTM) D1586 Standard Method for Penetration Test and Split-Barrel Sampling of Soil, as modified from ASTM D1586-99 (using a 3-inch O.D. split-barrel sampler and a 340-pound drop hammer with a 30-inch free fall). As described in the SCWP and SAP, soil samples were generally collected at 2.5-foot intervals from the ground surface to the water table and at 5-foot intervals from the water table to 30 feet BGS. In the deeper borings, soil samples were collected from within each 10 to 20-foot interval from the ground surface to the bottom of the boring. Soil samples were classified according to the Unified Soil Classification System. These classifications, used in characterizing the geology, are shown on the boring logs in Appendix B and discussed in Section 3.3.

Soil samples from shallow borings were field-screened for potential volatile organic contaminants using a photoionization detector (PID), as described in the SAP. The field representative also noted the presence of hydrocarbon odors, staining, and oily sheens. Field-screening results are shown on the boring logs in Appendix B and are discussed in Section 3.6.2. Field-screening results were used to select soil samples for laboratory analysis, as described in Section 2.4.1.

All investigation derived-waste, including drill cuttings, was managed in accordance with the SAP.

2.3.1.3 Permafrost Delineation

The SCWP proposed tasks to characterize permafrost occurrence to the extent that it affects sulfolane movement in groundwater. Permafrost occurrence data are being compiled from the plume delineation boring logs, logs from other investigations, and from available residential wells to build a three-dimensional representation of the permafrost.

When encountered, permafrost was sampled to characterize the nature of the frozen soil. The presence of permafrost in soil borings and monitoring wells has been evaluated using several types of information, including sample collection, drill action, and blow counts. If frozen soils were suspected, samples were collected from undisturbed soil, then immediately retrieved for visual classification. The sampler was not floated to the next sample interval before retrieval. Drilling was ceased once frozen soil was confirmed. To date and as directed by ADEC, no site characterization well borings have penetrated permafrost and no wells have been installed below the permafrost in the subpermafrost aquifer. All wells have been installed above permafrost in the suprapermfrost aquifer.

The permafrost samples were classified using the ADOT&PF system, based on ASTM D4083 and Linnell and Kaplar, *Description and Classification of Frozen Soils* (1966) in accordance with the SCWP.

Well construction logs were obtained from various sources (private well owners, Alaska Department of Natural Resource [ADNR] Well Log Tracking System [WELTS] database, and the ADEC Domestic Onsite wastewater disposal system files) for permafrost evaluation. The logs were reviewed for references to permafrost, which have typically been noted by the field geologist as “frozen,” without further classification.

Results to date of permafrost logging and review of historical boring logs are presented in Section 3.4.

Historical aerial photographs of the area have been obtained and are being reviewed to aid in the preparation of a three-dimensional model of the permafrost. Results will be discussed in the Site Characterization Addendum.

2.3.1.4 Grain-Size Distribution Analysis

As proposed in the SCWP, soil samples were collected from the screened intervals of several delineation wells for analysis of grain-size distribution (gradation) to aid in aquifer characterization. Samples were collected as follows:

- From Phase 1 wells MW-151C, MW-153B, MW-154B, MW-156B, MW-160B, MW-162B, MW-170C, and MW-173A/B.
- From Phase 2 wells MW-144B, MW-158B, MW-161B, MW-163B, MW-164B, MW-165B, MW-169B, MW-174B, MW-175, MW-176A/B/C, MW-177, MW-178C, MW-179C, MW-180C, MW-181A/B, MW-182, MW-183, MW-184, MW-185A/B, MW-186B/C, MW-187, O-1, O-2, O-3, and O-4.

Sample were not collected from Phase 2 wells MW-155 and MW-188 due to poor sample recovery. The samples were analyzed by SWI’s soils laboratory in accordance with ASTM D 422-63. Grain-size distribution charts are provided in Appendix C. Results are discussed in Section 3.5.

2.3.1.5 Well Construction

The monitoring and observation wells were installed and constructed generally in accordance with the methods outlined in the SCWP and SAP.

Homestead installed the shallow monitoring wells to depths of approximately 11 feet to 25 feet BGS. The wells were typically constructed of 2-inch diameter PVC with 10-foot long well screens, although 5-foot long screens were used for wells MW-150A, MW-151A, MW-152A, and MW-153A. Deeper wells were typically constructed using 5-foot screens, since there was no need to span the water table. MW-170B was installed with 4-inch-diameter casing and screen to allow the well to be used for potential aquifer testing in the future. Well screens with slot sizes of 0.010 or 0.020 inches were installed, depending on the geology observed during installation.

Homestead completed the majority of offsite wells with monuments set flush with the ground surface, except for wells MW-151C, MW-154A, MW-154B, MW-156B, MW-166A, MW-166B, MW-169A/B, and MW-187, which were installed with aboveground monuments. Homestead completed each of the onsite wells with an aboveground monument.

A registered land surveyor determined the well locations, ground surface elevations, and top-of-casing elevations. These data have been compiled with the survey information collected for existing wells and are shown in Table 1.

2.3.1.6 Well Development

The wells were typically developed by SWI no sooner than 48 hours after installation.

During Phase 1 of well installations, due to cold weather conditions and the desire to quickly delineate the sulfolane plume during the winter season, several wells were developed and sampled sooner than the standard 48-hour period. These included monitoring wells MW-155A, MW-156A, MW-157, MW-158A, MW-159, and MW-160A installed in November 2009; well MW-164A installed in December 2009; well MW-165A installed in January 2010; wells MW-169A and MW-171A installed in February 2010; and well MW-171B installed in March 2010. These wells were developed and sampled during cold weather conditions (temperatures less than -18°C [0°F]) and developed initially by over-purging (greater than 10 well volumes until water was visually clear); each of these sulfolane delineation wells were more thoroughly developed by surging and over-purging in April 2010.

In accordance with the SAP, during Phase 2, each of the wells was developed no sooner than 48 hours after installation by surging and over-purging.

All development water was containerized into drums which were transported to NPR for disposal in FHRA's wastewater treatment system, as described in the SAP.

2.3.2 Ground Penetrating Radar Survey

A geophysical survey was conducted by ARCADIS U.S., Inc. (ARCADIS) in order to further define the physical setting, in addition to the tasks proposed in the SCWP. The survey utilized ground penetrating radar (GPR) and was conducted along existing roadways both within NPR and offsite.

The objectives of the geophysical survey were to:

- Map the occurrence and distribution of coarse-grained, channel facies deposits within the greater floodplain of the Tanana River that represent potential preferential pathways for groundwater and contaminant transport within the shallow suprapermafrost aquifer; and
- Determine depth to permafrost, if feasible.

GPR is a non-intrusive survey method used to identify variations in subsurface conditions, based on differences in physical properties (specifically, the dielectric constant) of the subsurface materials. The GPR system simply transmits high-frequency electromagnetic waves into the ground and detects the energy reflected back to the surface. Energy is reflected along subsurface interfaces that possess different electrical properties. Reflections typically occur at lithologic contacts or where different subsurface materials exhibit high electrical contrasts, including more highly resistive, coarse-grained sediments in a finer sediment matrix. These reflections are detected by the antenna and processed into an electrical signal which can be used to provide an image of the feature.

Site-specific conditions such as soil type and moisture content control the effective depth of the survey. Conductive soils (i.e., clays) rapidly attenuate the GPR signal and limit the depth of investigation to a few feet or less, whereas resistive soils may allow an investigation depth of 40 feet or more. GPR was found to be effective in the vadose zone and the shallow suprapermafrost aquifer in the vicinity of NPR.

The survey was conducted along the roadways shown on Figure 1 of Appendix D. Approximately 15 linear miles of paved roadway and 5 linear miles of unpaved roadway were surveyed. Specific details of the methodology, including data acquisition and processing, are included in Appendix D. Results are discussed in Sections 3.3 and 3.4.

2.3.3 Groundwater Elevation Monitoring

As proposed in the SCWP, FHRA has initiated a program to monitor groundwater elevations onsite and offsite, utilizing an extensive network of monitoring wells, observation wells, and recovery wells. The elevations are completed by both manual and automated means.

2.3.3.1 Manual Measurements

Groundwater elevations were calculated from manual depth-to-water measurements that are completed at each monitoring well during each sampling event. Measurements were completed in accordance with the procedures in the SAP. The location and frequency of the groundwater monitoring events were described in Table 8 of the SCWP and shown on Figure 5 of this report. In addition, groundwater elevation measurements were to be completed monthly in 29 wells, and quarterly in 84 wells. The actual number of wells at which depth-to-water measurements were made during the 4th quarter of 2010 and the 1st quarter of 2011 were as follows:

4 th Quarter of 2010	Monthly Measurements			Quarterly Measurements
	October 2010	November 2010	December 2010	
	19 of 53	16 of 69	6 of 70	
35 of 84				

1 st Quarter of 2011	Monthly Quarterly Measurements			Quarterly Measurements
	January 2011	February 2011	March 2011	
	26 of 70 wells	13 of 70	20 of 70	
56 of 84				

The ability to complete field work during this period was affected by the onset of extreme winter conditions. First, due to the limited amount of time during which conditions were favorable, in accordance with the revised SAP, for field work, a priority was placed on completing groundwater sampling before completing groundwater elevation measurements at wells not scheduled to be sampled. Therefore, groundwater elevations in several wells were not measured. Second, the number of wells which were sampled was restricted due to temperatures below -5°F, increasing snow pack depth, and limited daylight. The SCWP's revised SAP includes a provision for not collecting samples during periods of extreme cold weather, defined as ambient temperatures or chill factors colder than -5°F. Therefore, several wells were not sampled and, thus, their groundwater elevations were not measured.

Groundwater elevations for wells in which LNAPL was present were calculated using depth-to-water measurements, the LNAPL thickness measurements, and the specific gravity of the LNAPL, as described in the SAP. LNAPL specific gravities were determined, as described in Section 2.5.4. Groundwater elevation data are presented in Table 2.

2.3.3.2 Automated Measurements

In addition to manual water level measurements, measurements were also completed using Global Water WL-16 automated water-level loggers (<http://www.globalw.com/products/wl16.html>). Each WL-16 is a combined pressure transducer and data logger with automatic barometric pressure and

temperature compensation. Each logger was calibrated to provide a direct elevation (above mean sea level) reading and programmed to measure water levels on an hourly basis. Transducers were installed in the suprapermafrost monitoring wells shown in Table 3. The table shows that five well nests were utilized in order to observe differences in groundwater elevations between wells installed at various depths within the suprapermafrost aquifer, in order to observe vertical gradients. Data from the loggers are presented in Appendix E. Results are discussed in Section 3.5.

2.3.4 Geochemical Analyses to Evaluate Subpermafrost Sulfolane Results

Sulfolane has been detected in groundwater samples collected from several residential wells with screens believed to be set below permafrost; however, it is unknown whether these data are truly representative of the subpermafrost aquifer. Due to construction methods and potential use of heat tracing to maintain flow in the wells, it is possible the permafrost around these wells has thawed, allowing for cross-contamination and pumping from the shallow suprapermafrost aquifer. It is also possible that the shallow portions of the subpermafrost wells' casings are compromised, allowing shallow sulfolane-impacted water to enter the wells.

Because drilling through the permafrost in an attempt to reach regions beneath permafrost zones is not currently desirable and because the geochemistry is believed to vary between the suprapermafrost and subpermafrost aquifers, the SCWP proposed using geochemical means to evaluate the deep private well data. Specifically, the SCWP proposed collecting groundwater samples from the subpermafrost residential wells and analyzing the samples for geochemical parameters. The results would be compared to data from known deep and shallow well data to determine if the residential wells in question are potentially drawing water and contaminants from the suprapermafrost aquifer.

Three areas were identified where residential wells yielded samples containing sulfolane, and where available information suggested these wells were constructed in the subpermafrost aquifer (Figure 6). Groundwater samples were collected from these subpermafrost residential wells for field and laboratory analysis as proposed in the SCWP. Samples were also collected for comparison purposes from suprapermafrost monitoring wells near the residential wells, and in other areas; samples were collected March 4, and March 9 through 12, 2011. Table 4 lists the wells sampled and the well screen depths. The depths of permafrost BGS are based on well installation logs for the residences and monitoring wells, or anecdotal information from residents and, as such, may not be completely reliable.

Temperature, conductivity, pH, dissolved oxygen, and oxidation/reduction potential were measured using a field meter at the time of sample collection. In addition, total and reduced iron and manganese were measured in the field using a Hach Co. DR/2010 meter and reagents. Other analytes were determined by SGS Environmental Services, Inc. (SGS) and included: sulfolane, ammonia, phosphate, total organic carbon, alkalinity, pH, sulfate, chloride, nitrate, nitrite, fluoride, sodium, potassium, calcium, magnesium, antimony, arsenic, barium, chromium, copper, beryllium, cadmium, mercury, nickel, selenium, silver, thallium, and zinc. Results of the analysis are discussed in Section 3.10. Laboratory reports are presented in Appendix F.

2.4 Characterize Soil Impacts

Historically, limited investigations of potential soil impacts at NPR have been completed due to the fact that the water table is very shallow, and the stability of the benzene and LNAPL plumes indicated the pump and treat remediation system was capturing the plumes, including contaminants that could be leaching from potentially impacted vadose zone soils. A summary of historical data gathered during SWI's previous investigations is presented in Section 3.6.1. The sections below discuss the characterization of soil impacts during site characterization, an investigation of NPR sumps, and the NPR laboratory investigation. Sampling locations are shown on Figure 7.

A comprehensive onsite soil investigation was not completed during the winter of 2010/2011 due to the inherent difficulties in collecting, field screening, and handling soil samples during extreme cold weather. FHRA is planning to complete the onsite investigation during the summer of 2011, as described in Section 8.1.

2.4.1 Site Characterization

As discussed in Section 2.3, soil samples from well borings were field-screened for the presence of contaminants. Field-screening results were used to select soil samples for laboratory analysis.

During Phase 1 of the well installations, select soil samples were submitted to SGS for laboratory analysis of sulfolane by modified USEPA Method 8270D. Samples were submitted from the following Phase 1 wells: MW-151C, MW-154B, MW-156B, MW-160B, and MW-162B. Sampling depths are shown in Table 5. The results of these analyses are discussed in Section 3.6.2. The quality assurance/quality control (QA/QC) review of the laboratory data is provided in Section 6.

During the Phase 2 well installation, one soil sample was collected from each boring exhibiting organic vapor concentrations greater than 20 parts per million (ppm), and from each boring drilled onsite at the refinery, as described in the SAP. Soil screening results are discussed in Section 3.6.2.

Soil samples from all of the Phase 2 offsite borings exhibited organic vapor concentrations less than 20 ppm; therefore, no samples from these borings were submitted for laboratory analysis. Soil samples from onsite borings yielded organic vapor concentrations up to 1,558 ppm. Soil samples were submitted for laboratory analysis from well borings MW-144B, MW-174A/B, MW-175, MW-176A/B/C, MW-177, MW-178A/B/C, MW-179A/B/C, MW-180A/B/C, and O-1 through O-4. Sample depths are noted in Table 5. The samples were submitted for sulfolane analysis, as well as for BTEX by Environmental Protection Agency (EPA) Method 8021B, VOCs using USEPA Method 8260B, SVOCs by USEPA Method 8270D, GRO by Alaska Method AK101, and DRO by Alaska Method AK102 in accordance with the SAP. The results of these analyses are discussed in Section 3.6.2. The quality assurance/quality control (QA/QC) review of the laboratory data is provided in Section 6. Laboratory reports are provided in Appendix F.

Additional analyses of soils related to LNAPL characterization is described in Section 2.5.3.

2.4.2 Laboratory Drain Investigation

In 2009 through 2010, a third-party inspection contractor was obtained to inspect the integrity of sumps and drain lines associated with NPR operations. A total of 42 sump systems were inspected, beginning in 2009 and continuing until inspections were completed in 2010. Four sump systems and the QC laboratory drain lines were found to have potentially compromised integrity. The four sump systems are discussed below in Section 2.4.3. The following text describes the investigation of the laboratory drain lines.

In July 2010, a hydrostatic pressure test of the laboratory drainage piping indicated that the subsurface piping system would not maintain a static water level when the piping system was isolated and filled with water. On July 21, 2010, FHRA reported these test results by letter to the ADEC.

In a December 22, 2010 letter, ADEC requested volume estimates and an investigation plan for the four sumps that failed the integrity testing conducted by FHRA. A work plan to assess the laboratory drain lines, and which discussed assessment activities previously conducted for the other failed sumps, was submitted to ADEC on March 17, 2011. At the request of ADEC, revisions were made, and the work plan was finalized on March 21, 2011.

A second round of hydrostatic testing was completed on the laboratory drain lines in March 2011. The additional testing in the laboratory was conducted in an effort to confirm the integrity of the

lines in certain portions of the laboratory. The testing confirmed the integrity of the drain lines in the water laboratory, and so no assessment activities were planned in this area (Appendix G).

2.4.2.1 Limited Site Investigation

Five soil borings (SBLAB-1 through SBLAB-5) were installed on March 28 and 29, 2011, beneath the laboratory building to assess the potential for a release from the suspect drain lines, as outlined in the Laboratory Area Subsurface Investigation Work Plan (ARCADIS, 2011). The soil boring locations were selected during a site visit with ADEC in December 2010, and were based on the drain usages in the FHRA QC laboratory and on a hydrostatic evaluation of the drain lines of the laboratory building. The boring locations were placed near drains and drain lines that were classified as “high use” by laboratory personnel, and are lines that also failed hydrostatic integrity testing. The locations of the soil borings are shown in Appendix G.

2.4.2.2 Soil Boring Installation

To access soils beneath the laboratory building, the concrete floor of the laboratory building was cut by a concrete-cutting contractor. Prior to cutting the concrete, FHRA verified the locations of the underground utilities and marked locations suitable for soil boring installation. The boring locations were modified based on the presence of underground utilities in the FHRA QC laboratory, but were placed as close to their original designations as possible.

Upon removal of the concrete from each boring location, a hand auger and other manual methods, including breaker bars and post-hole diggers, were used to reach the maximum depth possible. After attempting two boring locations, it was determined that manual methods would not be effective for advancing the borings to the groundwater interface. The presence of large cobbles and unconsolidated fill contributed to borehole collapse as the borings were advanced. After consultation with ADEC, the project team determined to use a vacuum truck to continue borehole clearance to the extent possible. For each location, manual methods were used to advance the boring as deep as possible (generally 2 to 3 feet BGS). A soil sample was collected at the maximum depth of manual clearance at each location for laboratory analysis. The vacuum truck was then used at each location in an attempt to advance the borings to the groundwater interface. Due to continued borehole caving and concerns about compromising the integrity of the laboratory floor, none of the borings could be advanced to the groundwater interface. However, at each location, a second soil sample was collected with the hand auger from below the maximum depth achieved with the vacuum truck (between 4 and 7 feet BGS); this sample interval was also submitted for laboratory analysis. The depths achieved in each of the five soil boring locations per clearance method (manual clearance or

vacuum truck) are summarized in Table 6. The soil boring installation activities were coordinated and phased to minimize interruptions to laboratory operations.

2.4.2.3 Field Screening

Field screening of soil samples was performed continuously during manual soil boring installation activities using a PID and visual classification. Soils were placed into a sealable plastic bag and allowed to volatilize for at least ten minutes, but no more than sixty minutes. A PID was then inserted into a small opening of the plastic bag and used to read the level of organic vapors in the bag. During borehole advancement with the vacuum truck, samples were collected for field screening on approximately two-foot intervals. The organic vapor concentrations were recorded on the boring logs included in Appendix G. Field screening also included a visual inspection of soils for the presence of LNAPL, hydrocarbon odor or hydrocarbon sheen on the soils. Lithologic descriptions and soil classifications were conducted by trained ARCADIS field staff and recorded on the boring logs included in Appendix G.

2.4.2.4 Soil Sample Collection

The subsurface material encountered beneath the laboratory building during soil boring installation was poorly-graded gravel with coarse sand and is assumed to be the compacted gravel bedding placed during construction of the building. Depth to groundwater was estimated to be approximately eight feet below ground surface. Due to the densities of subsurface fill and native soils, the equipment available for use, and borehole sidewall failure, it was not possible to reach the groundwater interface in soil borings SBLAB-1 through SBLAB-5. Soil samples were collected at the base of the manually-cleared portion of the borehole and at the base of the vacuum-cleared portion of the borehole from each soil boring location. ARCADIS field staff collected and handled analytical samples in accordance with the Draft Field Sampling Guidance (ADEC, 2010).

2.4.2.5 Soil Sample Analytical Methods

The soil samples collected during the installation of soil borings SBLAB-1 through SBLAB-5 were submitted to SGS in Fairbanks, Alaska for analysis of sulfolane, GRO, DRO, VOCs, and SVOCs in accordance with the methods listed in the SAP. In addition, samples were analyzed for residual range organics (RRO) by Alaska Method AK 103 and Resource Conservation and Recovery Act (RCRA) 8 metals by United States Environmental Protection Agency (USEPA) Method SW6020/7471B. Results of the laboratory drain investigation are presented in Section 3.6.3.

2.4.2.6 Soil Boring Abandonment

As noted previously, the project team was not able to reach the groundwater interface using available boring installation methods. ARCADIS and FHRA consulted with ADEC, and received verbal and email approval to abandon the soil boring locations on March 30, 2011. Soil borings SBLAB-1 through SBLAB-5 were backfilled with hydrated bentonite chips to approximately one foot BGS. Approximately 0.5 feet of soil removed during soil boring installation was then placed above the hydrated bentonite chips in each boring. The concrete cores previously removed were placed back in each borehole to be cemented back in place by FHRA.

All IDW including soil cuttings generated during the soil boring installation and not used as backfill material were managed in accordance with the SAP.

2.4.3 Sump Investigation

As indicated in Section 2.4.3, a total of 42 sump systems were inspected and four sump systems were found to have potentially compromised integrity. The four sump systems were identified as the Asphalt Sump (03-6), the Blend Building Sump (05-7), the Tank Farm Truck Kero Sump (922), and the Naphtha 2 Sump (02/04-2) (Figure 7). The results of the investigations at these four sumps were previously presented in a letter report to ADEC in December 2010 (FHRA, 2010) (Appendix H); therefore, many of the details of those investigations are not reiterated here.

2.4.3.1 Asphalt Sump

The results of the inspection of the Asphalt Sump indicated that leaks were confined to the inner steel shell of the sump. An attempt to remove the inner shell was unsuccessful, so the entire sump was replaced. The gravity drain lines, catch basins, and floor drains influent to the sump were tightness tested using the hydrostatic pressure test method. All elements were found to be leak free (Appendix H).

Approximately 10 cubic yards of soil were excavated during sump replacement in October 2010. Five soil samples were field screened using a PID, and one sample with elevated organic vapor concentrations was selected for laboratory analysis. The samples were analyzed for GRO, DRO, RRO, BTEX, and RCRA metals (Appendix H). Results of the investigation are discussed in Section 3.6.4.

2.4.3.2 Blend Building Sump

The inspection of the Blend Building Sump indicated that corrosion was confined to the inner steel shell of the sump. A six-inch layer of concrete was placed on the floor of the sump and a new floor

was welded into place. A new six-inch ring was welded over the corroded portion of the shell. No soil samples were collected near the sump since the area is paved and no excavations were completed at the sump (Appendix H).

The floor drains and cleanout fittings were inspected and three floor drain/trap assemblies and two cleanout fittings were excavated and replaced. Following all repairs to the sump and fittings, a hydrostatic pressure test was completed and the system was found to be leak free (Appendix H).

Two soil samples were collected from below the floor slab during replacement of a floor drain and a cleanout fitting. The samples were analyzed for GRO, DRO, RRO, BTEX, polynuclear aromatic hydrocarbons (PAHs), SVOCs, and sulfolane (Appendix H). Results of the investigation are discussed in Section 3.6.4.

2.4.3.3 Tank Farm Truck Kero Sump

FHRA did not identify any leak from the Tank Farm Truck Kero Sump, or any integrity issues in the lines that serve the sump. The sump was replaced due to aging and end-of-service life considerations (Appendix H).

Following removal of the sump, a soil sample was collected from beneath the sump's former location in September 2010. Due to high water table conditions and a lack of a suitable alternate sampling location, the sample saturated with groundwater was collected. The sample was analyzed for GRO, DRO, RRO, BTEX, PAHs, SVOCs, and sulfolane. Two samples of the soil that was excavated during sump replacement in October 2010 were analyzed for GRO, DRO, RRO, BTEX, and RCRA metals (Appendix H). Results of the investigation are discussed in Section 3.6.4.

2.4.3.4 Naphtha 2 Sump

Inspection of the Naphtha 2 sump indicated that the interior shell had been improperly installed in 1997. In addition, a gravity line from CU #2 failed a hydrostatic test. The sump was repaired and the drain line from CU #2 was permanently removed from service. Since the entire area is paved and no excavations were performed during sump repair, no soil samples were collected (Appendix H).

2.4.4 Other Historical Soil Data

SWI provided historical soil data from four soil borings, four monitoring well borings, and fifteen surficial soil sampling locations. Results are discussed in Section 3.6.1.

The four soil borings were placed during 2001, south of containment area CA5A/5B (B-1), east of containment area CA4 (B-2), at the southeast corner of containment area CA1 (B-3), and west of the

railcar-loading area (B-4) (Figure 7). One sample from each boring was submitted for laboratory analysis of GRO, DRO, RRO, VOCs, SVOCs, and metals. The samples were collected at depths that ranged from 7.5 to 11.5 BGS, likely near the zone of water table fluctuations (Appendix I).

The four monitoring wells were also installed in 2001. MW-135 was installed near the northeast corner of containment area CA7. The other three wells (MW-139, MW-141, and MW-142) were installed downgradient of the current truck-loading area (Figure 7). One sample from each boring, collected near the water table, was submitted for laboratory analysis. All samples were analyzed for GRO and DRO, and RRO. The MW-135 sample was analyzed for VOCs, SVOCs, and metals. The MW-139 and MW-140 samples were analyzed for BTEX and metals. The MW-142 sample was also analyzed for BTEX (Appendix I).

Thirty shallow (three feet BGS or less) soil samples were collected from 15 sampling locations along the railcar-loading area in 2004. All samples were analyzed for DRO and RRO (Appendix I).

2.5 Characterize NAPL

The SCWP identified data needs in the understanding of NAPL characteristics and occurrence, and proposed tasks to address those needs. Results are being used to confirm the stability of the LNAPL plume and monitor the effectiveness of the interim removal actions. As these are long-term goals, several of the proposed tasks are ongoing and will continue as IRAP implementation continues.

2.5.1 LNAPL Monitoring

As proposed in the SCWP, FHRA has initiated a program to monitor LNAPL using an onsite network of monitoring wells, observation wells, and recovery wells screened across the water table. The apparent LNAPL thicknesses were measured in accordance with the SAP. The proposed locations and frequencies of the LNAPL monitoring program were shown in Table 8 of the SCWP and shown on Figure 8 of this report. In accordance with the SCWP, four water table observation wells (O-1, O-2, O-3, and O-4) were installed at the locations shown on Figure 8 to fill data needs regarding the lateral extent LNAPL. The wells were constructed, as described in Section 2.3.1.

Twenty-eight wells were to be checked monthly and 21 were to be checked quarterly. The actual number of wells at which LNAPL measurements were completed was as follows:

4 th Quarter of 2010	Monthly Measurements			Quarterly Measurements
	October 2010	November 2010	December 2010	
	19 of 28 wells	3 of 28 wells	0 of 28 wells	

1 st Quarter of 2011	Monthly Quarterly Measurements			Quarterly Measurements
	January 2011	February 2011	March 2011	
	0 of 28 wells	4 of 28 wells	16 of 32 wells	
				5 of 21 wells

As previously discussed, field work during the fourth quarter of 2010 and the first quarter of 2011 was affected by the onset of extreme winter conditions. Due to a lack of favorable conditions, , as prescribed in the revised SAP, a priority was placed on monitoring well sampling over LNAPL thickness measurements. Since many of the locations proposed in Table 8 of the SCWP were included to monitor LNAPL and water table responses to interim removal actions, and, as discussed in Section 5, expansion of the groundwater and LNAPL recovery systems undergoing completion, a lower priority was placed on obtaining these measurements. LNAPL thickness measurements are shown in Table 2.

As proposed in the SCWP, four observation wells were installed at the locations shown on Figure 8. The wells were installed to address data needs in the understanding of LNAPL occurrence in areas downgradient of CUs #1 and #2, downgradient of containment areas CA4 and CA6, and downgradient of the former truck-loading area.

The wells were installed during Phase 2, with wells O-1 through O-3 installed on September 23, 2010, and O-4 installed on September 16, 2010. The wells were installed by Homestead following the drilling and soil sampling techniques described in Section 2.3.1. LNAPL monitoring results for these new wells are included in Section 3.7.1. Smear zone chemical profiling completed in conjunction with the installation of the O-wells is described below in Section 2.5.3.

2.5.2 Bail-down Testing

Bail-down testing is being completed to provide an estimate of LNAPL recoverability. SWI attempted to complete LNAPL bail-down tests at four wells on March 17 and 18, 2011:

- S-21, near Containment Area CA5;
- S-33, near Containment Area CA6;
- S-51, near the former truck-loading rack; and
- MW-138 near CU #2.

S-33 could not be located, possibly due to being buried in snow (Appendix J); therefore, nearby well S-44 was tested in its place. S-21, S-51, and MW-138 are 2-inch diameter wells, while S-44 is a 4-inch diameter well. The wells are shown on Figure 8.

The bail-down tests followed the procedures presented in Section 3.2.3.3 of the SAP (Appendix M of the SCWP). The field team used a Solinst Model #122 oil/water interface probe to measure the depth to LNAPL and depth to water, then calculated the thickness of LNAPL in the well. This information was then used to calculate the quantity of LNAPL to be removed from the well during the bail-down phase of the test as prescribed by the method.

A peristaltic pump was used to remove LNAPL from the wells, with the tubing intake set near the surface of the LNAPL layer to avoid removing water. The field team used the interface probe to measure LNAPL thickness during bail-down pumping to determine when the LNAPL layer was removed from the well casing (i.e., LNAPL thickness not measureable using the interface probe). Once the calculated volume of LNAPL had been removed and the accumulated LNAPL in the well casing had been removed, the pump was shut off and LNAPL recovery gauging began. Well S-44 was an exception; less than half the calculated volume of NAPL was removed because of slow recharge.

Product recovery monitoring consisted of measuring depth to LNAPL and depth to water from the designated measuring point at the top of the well casing. Measurements were generally taken at one- to two-minute intervals for the first five minutes, two- to five-minute intervals from five to fifteen minutes, and five- to fifteen-minute intervals from fifteen minutes to the end of each test. The measurements and times of the readings were recorded on the field logs (Appendix J). The tests were concluded when the field personnel determined that LNAPL thickness had stabilized, in accordance with the procedure (maximum 0.03-foot change over previous measurement).

At well S-21, approximately 0.2 gallons of LNAPL were removed, then the pump was shut off to allow additional LNAPL to flow into the well casing. Pumping was resumed until a cumulative 0.4 gallons were removed. Approximately 0.6 gallons of water were removed from the well in addition to the LNAPL.

Approximately 0.7 gallons of LNAPL were removed from well S-44 before the pump was turned off to allow additional NAPL to flow into the well casing. Pumping was resumed, but the test was stopped when it became apparent that LNAPL recovery was very slow and more water was being removed from the well than desirable. The test procedure states less than one gallon of water should

be removed from the well; however, 1.2 gallons of water were removed with a cumulative 0.8 gallons of LNAPL. This was less than one-half the target volume.

At S-51, approximately 0.7 gallons of LNAPL were pumped from the well. The pump was then turned off to allow additional LNAPL to flow into the well casing. Pumping was then resumed until a cumulative 1.5 gallons were removed. Approximately 0.3 gallons of water were removed from the well in addition to the LNAPL.

At well MW-138, 0.6 gallons of LNAPL, or three times the target volume, were removed, along with 0.3 gallons of water. The extra volume of LNAPL removed during bail-down is attributed to the LNAPL rapidly recharging into the well during the bail-down process.

Bail-down testing field notes are provided in Appendix J. Results of the bail-down testing are presented in Section 3.7.3.

2.5.3 Smear Zone Chemical Profiling

As proposed in the SCWP, chemical profiling of the smear zone was completed during the installation of the new observation wells as part of LNAPL characterization. The smear zone is the layer of impacted soil above and below the water table, caused by the smearing of contaminants into the soil as the water table fluctuates up and down. The profiling identifies which LNAPL constituents are present in the soil.

As described in Section 2.3.1, during installation of wells O-1 through O-4 (O-wells), soil samples were collected only from the bottom of the borings or at intervals with PID measurements greater than 20 ppm. Additional soil borings (O-borings) were placed immediately adjacent to the O-wells on October 19 and 20, 2010, in order to obtain the necessary composite soil samples for the profiling. Soil samples were collected continuously, both above and below the water table, as specified by the SCWP. The soil samples from the two intervals above the water table and two intervals below the water table were used for the composite sample from each boring, as proposed in the SCWP. These composite samples were analyzed for sulfolane, GRO, DRO, VOCs, and SVOCs. The results of these analyses are discussed in Section 3.7.4. Laboratory analytical reports are included in Appendix F.

2.5.4 LNAPL Sampling and Analysis

LNAPL samples were collected and analyzed in order to obtain physical characteristics of the LNAPL, such as specific gravity, color, and viscosity. Analyses were also completed to determine

LNAPL constituents and obtain “fingerprint” data. The resulting data are being used to address data needs in the LNAPL conceptual model and are being used, or will be used, to evaluate potential sources, evaluate LNAPL as a source of dissolved-phase contaminants, and eventually estimate the volume of recoverable LNAPL. Specific gravity data are used calculate corrected groundwater elevations in wells with LNAPL.

LNAPL samples were collected from a total of nine wells from three areas of NPR on December 3 and 6, 2010. In accordance with the SCWP, samples of LNAPL were collected from:

- Well MW-138 in the CU #2 area;
- S-21 near containment area CA5A;
- S-33 near CA6; and
- S-51 near the former truck-loading rack.

Additional LNAPL samples were collected from five wells in order to further characterize LNAPL as follows:

- R-33 and MW-115 near CU #1 and #2;
- R-32 and S-22 near containment areas CA5A and CA5B; and
- S-39 near CA4.

The well locations are shown on Figure 8.

Prior to sampling, the depth of LNAPL in the well was gauged using an oil-water interface probe. Samples were then collected using a peristaltic pump. Only the amount of tubing needed to skim the LNAPL from the groundwater surface was deployed in order to avoid capturing groundwater. Samples were collected into the appropriate laboratory-provided sampling containers and submitted to SGS for determination of

- Specific gravity by ASTM International (ASTM) Method D-1298;
- Sulfolane content by USEPA Method 1625B; and
- Volatile organic compounds (VOC) content by USEPA Method 8260B.

The samples were also analyzed by Alaska Methods AK102/103 (equivalent to USEPA Method 8015B), to obtain a hydrocarbon “fingerprint,” as proposed in Section 6.6.3.1 of the SCWP.

The SCWP indicates USEPA Method 8270D would be used to analyze sulfolane; however, since the completion of the December 2010 LNAPL sampling, the laboratory, in consultation with Environmental Standards, Inc. (ESI), developed an additional standard operating procedure (SOP) that outlines the method for analyzing sulfolane in LNAPL. Therefore, USEPA Method 1625B was used to complete subsequent sulfolane analyses. On April 18, 2011, sampling was repeated at MW-138, S-51, and R32, and analyses were completed in accordance with the additional SOP.

The specific gravity method is also different than the method stated in the SCWP; Method ASTM D-1298 was used to analyze the specific gravity of LNAPL due to the method available at the SGS reference laboratory, Wyoming Analytical of Golden, Colorado.

The LNAPL samples were also submitted for analysis of color by ASTM D-1500 and viscosity by ASTM D-445 in order to further characterize the LNAPL constituents. Results of these analyses are discussed in Section 3.7.4. Laboratory reports are provided in Appendix K.

2.5.5 LNAPL Recovery from Remediation Systems

FHRA continues to remove LNAPL from recovery wells and monitoring wells through active product pumping systems, passive product recovery canisters, and through periodic removal with a vacuum truck. In addition, LNAPL unintentionally captured by the groundwater recovery system is captured in the coalescer and removed from the system so as not to continue through the air strippers. Further description of the LNAPL recovery efforts and results are provided in Section 5.1.1.2.

2.5.6 DNAPL Assessment

As stated in the SCWP, a 150-gallon release of sulfolane occurred in July 2002 at Tank 194 near CU #1 (Figure 3). Pure sulfolane is denser than water, with a specific gravity of 1.261, raising concerns regarding the potential for the formation of a dense non-aqueous phase liquid (DNAPL). According to a website maintained by the USGS Toxic Substances Hydrology Program (http://toxics.usgs.gov/definitions/dnapl_def.html), a DNAPL is defined as a liquid denser than water that does not dissolve or mix easily in water (i.e., it is immiscible). Given that sulfolane is miscible with water, a persistent DNAPL layer is not expected to be present. To determine the need for additional investigation regarding potential DNAPL, the SCWP proposed evaluating trends in dissolved-phase sulfolane data from existing and new monitoring wells.

As described in Section 2.3.1, eleven deep monitoring wells (i.e., screen depths greater than 50 feet BGS) were installed in 2010 in an area that is downgradient from the CUs and sulfolane storage Tank 194, including:

- Wells MW-174A, MW-176B, MW-178B, MW-179B, and MW-180B; installed to depths of approximately 37 to 40 feet below the water table; and
- Wells MW-174B, MW-175, MW-176C, MW-178C, MW-179C, and MW-180C; installed to depths of approximately 76 to 80 feet below the water table.

Well locations are shown on Figure 9. The wells were installed and constructed as described in Section 2.3.1. Exact construction details for these wells are presented in Table 1. Groundwater samples collected from these wells provide information regarding groundwater quality and the possible presence of a DNAPL sulfolane layer. Another five existing deep monitoring wells are located downgradient from those listed above, and samples from these wells provide additional information about the vertical distribution of sulfolane downgradient of a potential DNAPL layer. These five wells include:

- MW-101, installed to a depth of approximately 48 feet below the water table;
- Wells MW-102 and MW-154A, installed to depths of approximately 52 and 62 feet below the water table, respectively; and
- Wells MW-144B and MW-154B installed to depths of approximately 77 and 88 feet below the water table, respectively.

These wells' locations are also shown on Figure 9, and their construction details are provided in Table 1.

Groundwater samples were collected from these sixteen wells during 2010 and/or the first quarter of 2011, and analyzed to determine sulfolane concentrations and to begin the process to determine if an additional investigation regarding potential DNAPL is necessary. Results are discussed in Section 3.7.6. Laboratory analytical reports are in Appendix F.

2.6 Characterize Groundwater Impacts

Characterization of the dissolved-phase plumes is being completed by collecting and analyzing groundwater sampling from existing and new monitoring wells. Depending on the well location,

groundwater samples are analyzed for BTEX; 1,2,4-TMB; sulfolane; and/or natural attenuation parameters.

Evaluation of the resulting data for trends and responses to groundwater elevation fluctuations has started and will be continued as more data are collected. Evaluation of data has also begun with respect to natural attenuation of sulfolane, the results of which will eventually be used as part of a feasibility study of the offsite plume. To date, only one set of natural attenuation data have been collected.

Groundwater data will eventually be used as a tool to monitor the effectiveness of the IRAP, and then final corrective actions.

The process to identify additional COPCs in groundwater was discussed in Section 2.2 and the results are presented in Section 3.2. Recommendations regarding the groundwater analyses are presented in Section 8.0.

2.6.1 BTEX and 1,2,4-TMB

BTEX and 1,2,4-TMB are used as the primary indicators of petroleum impacts onsite. As proposed in the SCWP, analyses of groundwater samples for BTEX and 1,2,4-TMB are conducted at a subset of onsite wells screened at or near the water table. Wells are scheduled for sampling on a semiannual (second and fourth quarter of the year) or annual (second quarter) basis. The BTEX and 1,2,4-TMB monitoring network, as proposed in the SCWP and on Figure 10.

During the fourth quarter of 2010, a transition began from the former monitoring plan (Table 5 of the SCWP) to the revised monitoring plan (Table 9 of the SCWP). Groundwater samples were collected from the onsite network generally according to the sampling schedule presented in Table 5 of the SCWP. As a result, several wells listed in SCWP Table 9 were not sampled, including MW-116, MW-133, MW-148A, MW-148B, MW-149A, MW-149B, MW-153A, MW-153B, S-23, and S-41. Wells MW-115, S-20, and S-44 were not sampled due to the presence of LNAPL. The fourth quarter sampling was completed in October and November. Wells MW-106, MW-134, and MW-141 were not sampled during the fourth quarter, but were sampled in September 2010. Samples were collected in accordance with the SAP. Field sampling sheets are provided in Appendix L. Groundwater samples were submitted to SGS for BTEX analysis by USEPA Method 8260B. No analyses for 1,2,4-TMB were completed. Laboratory reports are included in Appendix F.

Although the revised monitoring plan proposed no sampling during the first quarter of 2011, samples were collected in February from wells MW-106, MW-109, MW-110, MW-111, MW-113, MW-124, MW-125, MW-126, MW-132, MW-133, MW-135, MW-139, MW-140, MW-141, MW-144A, and MW-145. They will be sampled again during the second quarter to maintain consistency with the SCWP schedule.

The first quarter 2011 groundwater sampling was conducted in accordance with the methods and procedures described in the SAP. Field sampling sheets are provided in Appendix L. Groundwater samples were submitted to SGS for BTEX and 1,2,4-TMB analysis by USEPA Method 8260B. Laboratory reports are included in Appendix F. The results are discussed in Section 3.8.

2.6.2 Sulfolane

As proposed in the SCWP, analyses of groundwater samples for sulfolane are conducted at monitoring wells completed at multiple depths within the suprapermafrost aquifer. Wells are scheduled for sampling on quarterly, semiannual (second and fourth quarter of the year) or annual (second quarter) basis. New onsite and offsite wells are generally sampled monthly for a period of six months following installation, then quarterly.

The SCWP divided the sulfolane monitoring network into vertical zones with respect to the water table: water table wells, wells screened 15 to 55 feet below the water table, wells screened 55 to 90 feet below the water table, and wells screened 90 to 160 feet below the water table.

The sulfolane monitoring network has been undergoing expansion in an effort to delineate the horizontal and vertical extents of the plume. The sulfolane monitoring network as proposed in the SCWP is shown on Figure 11.

Monitoring well sampling for sulfolane was conducted in accordance with the SAP. Field sampling sheets are provided in Appendix L. Groundwater samples were submitted to SGS for sulfolane analysis by USEPA Method 8270D in accordance with the SAP. Laboratory reports are included in Appendix F. The results are discussed in Section 3.8.

2.6.2.1 Monitoring Network Expansion Sequence

As noted above, the sulfolane monitoring network has been expanded to fill data needs, and the monitoring wells were installed in phases before submittal of the SCWP (Phase 1) and after submittal of the SCWP (Phase 2), as described in Section 2.3.1. Several wells were installed below the water

table to assess the vertical extent of sulfolane. Wells installed during Phase 1 and Phase 2 are shown on Figure 4 and construction details are shown in Table 1.

The primary goal during installation of the Phase 1 wells was to define the downgradient edge of the sulfolane plume. Therefore, the wells were installed moving northwest (downgradient) from NPR in a step-wise approach, with successive bands of monitoring wells installed following receipt of sulfolane results from previously installed wells. Final well locations were influenced by utility locations and access issues, both in the physical sense (e.g., could a well location be reasonably accessed by sampling technicians; did permafrost prevent the use of the location), and with consideration of property ownership (i.e., was the desired well location on public property).

The first series of wells was constructed to delineate the plume at the water table. Deeper wells were installed adjacent to the water table wells to delineate the vertical extent of the plume. If permafrost was encountered, a well was usually set just above the permafrost.

The sequence of well installation was as follows:

- Wells MW-150A/B through MW-152A were installed along North Pole High School Boulevard, and MW-153A was installed near the northern property boundary from October 2 through 7, 2009.
- Wells MW-155A through MW-160A were installed in Ford Subdivision between November 11 and 13, 2009, following the detection of sulfolane in groundwater samples collected from wells located along North Pole High School Boulevard.
- Wells MW-161A through MW-164A were installed along an east-west line approximately 2,000 to 5,000 feet downgradient of the Ford Subdivision between November 25 and December 10, 2009, following sulfolane detections at MW-155, MW-156A, MW-157, MW-158, and MW-159.
- Wells MW-165A through MW-168 were installed further downgradient, along an arc stretching from Richardson Highway to Badger Road from January 7 through January 18, 2010, following sulfolane detections at MW-161, MW-162A, MW-163, and MW-164.
- After groundwater samples from wells MW-161, MW-162A, MW-163, and MW-164 were reported to be nondetect for sulfolane, additional water table wells were installed to better

define the edges of the plume from February 25 to March 24, 2010, including MW-169A, MW-170A, MW-171A, and MW-172A.

The wells were placed at locations suitable for creating nests of multiple wells at various depths, if determined necessary for vertical plume delineation. Deeper wells with depths ranging from 32 feet to 150 feet BGS were installed adjacent to the shallow wells (Figure 4) as follows:

- MW-151C, MW-156B, MW-160B, MW-166B, MW-167B, MW-170B/C, MW-171B, and MW-172B; from February 17 to March 27, 2010 to further define the center and edges of the plume at depth.
- MW-154A (75.5 feet BGS) and MW-154B (95.0 feet BGS), were installed at NPR near existing shallow well MW-139 on October 5, 2009, and February 20, 2010, respectively, to delineate the plume at depth onsite.
- A shallow and deep well were installed along the northeastern property boundary to monitor water quality between NPR and The City's water supply wells. MW-173A was installed across the water table on March 31, 2010 and MW-173B was installed approximately 138 feet below the water table on March 30, 2010.
- Well MW-153B (56.7 feet BGS) was installed adjacent to MW-153A on April 20, 2010, to define the western edge of the plume at depth near the northern property boundary.

MW-153B was the last Phase 1 well installed prior to preparation of the SCWP. During evaluation of the data from the Phase 1 wells, data needs were identified with respect to the dissolved-phase sulfolane plume. Therefore, the SCWP proposed the installation of additional monitoring wells.

The additional wells were installed during Phase 2, which occurred from September 9, to November 24, 2010. Seventeen onsite and 17 offsite sulfolane delineation wells were installed during Phase 2. The wells were installed at the general locations and depths proposed in the SCWP, as well as some additional locations. As was the case during Phase 1, shallow wells were installed to address data needs in understanding of the plume at the water table, and deeper wells were installed to further define both the horizontal and vertical extent of the plume below the water table. The shallow wells include offsite wells MW-181A, MW-182, MW-183, MW-185A, and MW-187 (Figure 4). The deeper wells include onsite wells MW-144B, MW-175, and MW-177; and offsite

wells MW-155B, MW-158B, MW-161B, MW-163B, MW-164B, MW-165B, MW-169B, MW-170D, MW-181B, MW-184, MW-185B, and MW-188 (Figure 4).

The SCWP originally proposed a well southwest of MW-166A/B; however, due to access issues, the location was moved northwest. Multiple attempts were made to install the well on Benn Lane; however, permafrost was encountered at the ground surface and the borings were advanced 10 feet into the permafrost without finding the lower limit. Therefore, the location was moved further to the northwest and the new well (MW-188) was installed on Luckie's Lane November 24, 2010 (Figure 4).

The SCWP proposed a deep well near existing well MW-130. Due to access issues, the new well (MW-175) was installed approximately 250 feet east of this location.

In addition to the wells proposed in the SCWP, FHRA installed three additional onsite well nests to better define the horizontal and vertical extent of the onsite plume downgradient of CUs #1 and #2 and Lagoon C. Wells installed include MW-178A/B/C, MW-179A/B/C, and MW-180A/B/C (Figure 4).

2.6.2.2 Water Table Network

The water table wells from the sulfolane monitoring well network shown in Table 10 of the SCWP, and on Figure 11.

In addition to the new shallow monitoring wells described above, the SCWP proposed adding existing wells S-19, S-38, S-39, S-40, S-51, and MW-105A to the water table sulfolane monitoring network. Wells S-19 and MW-105A were proposed to monitor groundwater upgradient (south) of the CUs. Wells S-38, S-39, S-40, and S-51 were added to monitor the effects of recovery wells R-35, R-40, R-39, and R-21, respectively.

As was the case with the BTEX sampling network, the fourth quarter marked a transition from the former sulfolane monitoring plan (Table 5 of the SCWP) to the revised monitoring plan (Table 10 of the SCWP). Groundwater samples were collected generally according to the sampling schedule presented in Table 5 of the SCWP. As a result, several of the proposed wells were not sampled, including MW-104, S-40 and S-41. Wells MW-115, MW-138, R-21, S-20, S-21, S-38, S-39 and S-51 were not sampled due to the presence of LNAPL. Wells MW-106, MW-129, and MW-134, and MW-141 were not sampled during the fourth quarter, but were sampled during the third quarter. Most of the fourth quarter sampling was completed in October or November. Due to cold weather

restrictions, in accordance with the SAP, very few wells were sampled during December of 2010. The SCWP's SAP includes a provision for not collecting samples during periods of extreme cold weather, defined as ambient temperatures or chill factors colder than -5°F.

During the first quarter of 2011, monitoring wells were sampled as weather permitted between early January and late March. During the first quarter, out of 49 work days available for sampling, 26 days were warm enough to sample. The first quarter groundwater sampling period was ended March 11th to afford enough time for the laboratory analyses to be returned and subjected to quality assurance review for inclusion in this report. Most of the wells scheduled for quarterly sampling were successfully sampled during the first quarter of 2011. Wells S-38, MW-166A, and MW-179A could not be sampled because they were frozen. Wells S-39, S-40, S-51, and MW-176A were not sampled because LNAPL was present in the wells. Well MW-159 was inaccessible and could not be sampled because it was buried under a large snow berm. Well MW-160A was destroyed by a road grader in the summer of 2010. At the February TPT Meeting, ADEC has agreed that replacement of MW-160A is not necessary. Well MW-182 was not sampled because the monument was filled with frozen soil. Despite being scheduled for semiannual sampling, wells MW-106, MW-109, MW-110, MW-111, MW-113, MW-130, MW-132, MW-144A and MW-145 were sampled during the first quarter. They will be sampled again during the second quarter to maintain consistency with the SCWP schedule.

2.6.2.3 10 to 55 Feet below the Water Table

All of the wells in this depth interval that are sampled for sulfolane, and their sampling frequencies, are shown on Figure 11. The SCWP noted that several existing onsite wells screened between 10 and 55 feet below the water table are located downgradient of the tank farms and process areas. Wells in these areas include MW-101, MW-104, MW-127, MW-129, MW-147B, and MW-148B; therefore, these wells were added to the monitoring network. MW-105 was added as an upgradient monitoring location.

During the fourth quarter of 2010, all intermediate-depth wells scheduled for quarterly sampling were sampled during October or November. New wells scheduled for monthly sampling were sampled during October and November, but very few were sampled during December due to cold weather, in accordance with the SAP.

During the first quarter of 2011, most of the wells in this depth interval that are scheduled for quarterly sampling were successfully sampled. Wells MW-151C, MW-153A, MW-166B, and

MW-179B could not be sampled because they were frozen. Wells MW-152A and MW-152B were inaccessible and could not be sampled because they were buried under large snow berms. Despite being scheduled for semiannual sampling, wells MW-104 and MW-129 was sampled during the first quarter. They will be sampled again during the second quarter to maintain consistency with the SCWP schedule.

Monitoring well sampling was conducted in accordance with the SCWP SAP. Laboratory reports are included in Appendix F. The results are discussed in Section 3.8.7.

2.6.2.4 55 to 90 Feet below the Water Table

At the time the SCWP was submitted, only onsite wells MW-154A/B and offsite well MW-170B were available to monitor groundwater in the depth interval that is 55 to 90 feet below the water table. Therefore, new monitoring wells were installed as described in Section 2.6.2.1. The wells in this depth interval that are sampled for sulfolane are shown on Figure 11.

New wells scheduled for monthly sampling were sampled during October and November, but very few were sampled during December due to cold weather, in accordance with the SAP. Most of these wells were sampled between early January and late March 2011, during the first quarter of 2011. Wells MW-176C, MW-177, MW-178C, and MW-179C could not be sampled during the first quarter of 2011 because they were frozen. MW-154B and MW-160B were not sampled due to time constraints imposed by cold weather and the end of the first quarter of 2011.

Monitoring well sampling was conducted in accordance with the SCWP SAP. Laboratory reports are included in Appendix F. The results are discussed in Section 3.8.7.

2.6.2.5 90 to 160 Feet below the Water Table

At the time the SCWP was submitted, wells MW-170C, MW-172B, and MW-173B were available to monitor groundwater in the depth interval that is at least 90 feet below the water table. No new wells have been installed in this depth interval because:

- Wells MW-170C, MW-172B, and MW-173B have been nondetect for sulfolane;
- permafrost appears to be present below the footprint of the known shallow plume west of MW-170C, MW-172B, and MW-173B; and

- very few wells (MW-154A, MW-154B, and MW-160B) in the overlying interval (55 to 90 feet below the water table) have yielded samples containing sulfolane, and permafrost is known to occur below these wells.

The wells in this depth interval to be sampled for sulfolane are shown on Figure 11. The three wells were sampled during the first quarter of 2011, between early January and late March 2011.

All monitoring well sampling was conducted in accordance with the SCWP SAP. Laboratory reports are included in Appendix F. The results are discussed in Section 3.8.7.

2.6.2.6 Private Wells

A door-to-door survey was conducted in search areas located downgradient of NPR in order to identify private water supply wells. The search areas are shown on Figure 12. All permanent buildings were visited, and residents were requested to provide information regarding well presence, well construction details, and water usage. As of March 21, 2011, a total of 793 properties were visited within the search areas, and 487 were found to have a well. If a well was present, a request was made to collect groundwater samples to be tested for sulfolane, at no expense to the resident. Samples were collected from 404 wells. Eighty-three wells were identified from which samples were not collected for the following reasons:

- the wells were unused;
- the wells were dry or frozen; and/or
- the resident/owner already had an alternate water supply and, therefore declined to participate in the well sampling program.

In addition, in some cases, wells solely used for irrigation were not sampled.

Eighty-five additional samples were collected from wells outside the search areas if FHRA was contacted with a request for testing. Sampling locations are shown on Figure 12. Details of the search and sample methods are provided in *Residential-Well Search Survey, Areas 1 through 6B* (SWI, 2011 [in review]).

The private well sampling results are discussed in Section 3.8.7. Copies of laboratory reports have been provided to ADEC as they were provided to the well owner.

2.6.3 Monitored Natural Attenuation Evaluation

An Offsite Feasibility Study will be completed to evaluate potential remedies, including monitored natural attenuation (MNA), to address sulfolane-impacted groundwater occurring beyond the limits of NPR. The SCWP proposed collecting groundwater samples from several offsite monitoring wells and analyzing the samples for parameters that will, over time, provide the information necessary to evaluate the potential for natural attenuation of dissolved sulfolane.

2.6.3.1 Quarterly Groundwater Analyses

To assess whether microbially mediated natural attenuation of sulfolane may be occurring within the plume, concentrations of various parameters were measured to check for changes attributable to sulfolane biodegradation. Such changes may include decreases in concentrations of terminal electron acceptors, or increases in concentrations of biodegradation byproducts that coincide with decreases in sulfolane concentration.

As MNA is a remedial alternative that is under consideration for offsite sulfolane impacts, the sampling plan presented in the SCWP focused on collection of data from the following areas:

- Uncontaminated sidegradient monitoring wells;
- Wells located at different distances along the dominant groundwater flow path within the limits of the sulfolane plume, but outside the limits of the hydrocarbon plume; and
- Wells just outside the sulfolane plume.

The SCWP included 30 monitoring wells along the groundwater flow path and at the edge of the sulfolane plume to be sampled for MNA parameters, incorporating shallow and deeper wells to provide information regarding biodegradation activity with depth. The wells and rationales for sampling them are shown in Table 7.

Groundwater samples were collected for MNA parameters between February 10 and March 9, 2011. All but six of the wells listed above were sampled. Wells MW-152A, MW-152B, and MW-159 were inaccessible because they were buried under large snow berms. MW-160A was destroyed by a road grader in the summer of 2010, and wells MW-166A and MW-166A were frozen.

At each well sampled, the wells were first purged in accordance with the SAP. Following purging, field-based measurements were taken, and samples were collected for laboratory analysis by the

USEPA or Standard Methods for the Examination of Water and Wastewater, 20th Edition (SM20) methods shown in Table 7.

Samples collected for measurement of natural-attenuation parameters were submitted to SGS for analysis. SGS utilized the methods listed above for total organic carbon, alkalinity, and sulfate in accordance with Table 5 of the SCWP SAP. Additional natural attenuation parameters not specifically included in the SCWP were measured by SGS or using field-based methods. Total phosphorus, total Kjeldahl nitrogen total hardness, and nitrate/nitrite were determined using the methods listed in Table 7. Laboratory analytical reports are presented in Appendix F.

Field-based measurements of dissolved oxygen, conductivity, temperature, and pH were performed using a YSI ProPlus multiprobe, calibrated according to the manufacturer's instructions. Total and reduced iron, total and reduced manganese, and sulfide were measured using Hach Co. reagents and a DR/2010 field spectrophotometer following the manufacturer's protocols, with a few exceptions. Hach Co. reagents were not available for the iron measurements when the samples from wells MW-151A/B, MW-157, MW-162A/B, MW-163A, MW-164A, MW-165A, MW-167A/B, and MW-168 were collected; those samples were submitted to SGS for total iron analysis by USEPA Method 200.8, and dissolved iron analysis (in 0.45- μ m field-filtered samples) by the same method. Oxidized iron species are determined by the difference between total and reduced iron in the Hach Co. measurements, or between total and dissolved iron in the laboratory measurements.

Reduced manganese was determined using Hach Co. reagents and a modification of the protocol for total manganese analysis. The Hach Co. manganese analysis we used employs the "PAN method," which is capable of detecting low levels of manganese. In this method, an ascorbic acid reagent is added to the sample initially to reduce all oxidized forms of manganese to divalent manganese. After adding an alkaline-cyanide reagent to mask potential interferences, the PAN Indicator is then added to combine with the divalent manganese to form an orange-colored complex that is measured colorimetrically. Reduced manganese was measured in the samples by omitting the addition of ascorbic acid, which allowed measurement of the reduced manganese present in the sample prior to adding the reducing agent. Oxidized manganese is then determined by the difference between total and reduced manganese.

Sampling is planned to be conducted quarterly, but the frequency may be adjusted. The MNA data collected will be evaluated for trends in the MNA parameters along the flow path, with depth and with time. When sufficient data have been collected, the Mann-Kendall trend test will be applied to

the data to discern increasing or decreasing trends in the data with distance and time (subject to any constraints of the method relative to seasonal variability).

2.6.3.2 Isotherm Analyses

The decision to include isotherm analysis in the SCWP was driven by the better-than-expected performance of activated carbon adsorption as a treatment alternative for sulfolane-impacted water during treatment studies performed for IRAP and Point-of-Entry (POE) applications (see Section 5.0). The team believed it was important to verify the partitioning coefficient for sulfolane at the site to allow its comparison to published values. Such a comparison would confirm that sulfolane adsorption/desorption, as it relates to both natural attenuation progress monitoring, as well as fate and transport of sulfolane at the site, occurs to the extent originally anticipated based on published information.

FHRA will continue the practice of integrating information into its analysis that is obtained from other activities (e.g., POE bench and pilot testing) to inform and focus data collection plans in support of the feasibility study for remediation at the site. As POE pilot testing proceeds, and as pilot testing of the activated carbon system is conducted, a significant portion of the sampling and analysis associated with these efforts will focus on evaluation of biologically-mediated sulfolane degradation occurring in conjunction with these systems. The information learned from these activities will be used to help interpret data from ongoing MNA sampling, and to focus/augment data collection activities in support of the feasibility study.

The objective for isotherm testing outlined in the SCWP was to evaluate the possible amount of adsorbed sulfolane within the plume that may desorb during remediation/natural attenuation and affect the observed trends in sulfolane concentration by establishing site-specific distribution coefficients. To achieve this objective, a protocol was developed in consultation with ADEC and Dr. David Barnes (University of Alaska-Fairbanks) to evaluate the possible adsorption of sulfolane to aquifer material

As summarized in the SCWP, the protocol was originally developed as a desorption isotherm test, and consisted of:

- Collection of a sediment sample from a zone within the sulfolane plume, but outside the zone of LNAPL occurrence;
- Quantification of sulfolane within the sediment material;

- Equilibrating unimpacted (sulfolane-free) groundwater with the sediment in different water: sediment ratios;
- Measuring the resulting aqueous sulfolane concentrations; and
- Computing distribution coefficients from the data.

During development of the protocol, the team concluded that the analytical method for quantification of sulfolane in the aquifer sediment lacked the necessary sensitivity to support computation of distribution coefficients from the data. The approach was therefore modified to an adsorption isotherm test, in which a known amount of sulfolane (500 ppb) was spiked into clean groundwater, and then equilibrated with different amounts of aquifer sediment.

With respect to the original objective of the isotherm test described in the SCWP, modifying the protocol from a desorption test to an adsorption test carries the inherent assumption that adsorption of sulfolane to the aquifer sediment is fully reversible. Therefore, when using the results of the test to evaluate the amount of sulfolane that may potentially desorb during natural attenuation of the dissolved-phase sulfolane plume, it is important to note that the indicated amount may be conservatively high, as the adsorption process may not be completely reversible. Subsurface soil for the testing was collected from the boring for well MW-186C, installed on October 15, 2010.

Continuous split-spoon samples were collected from the boring starting at 50 feet BGS to a depth of 64.5 feet. The spoon was generally advanced about two feet per sample (actual sample intervals were 50 to 52 feet, 53 to 55 feet, 55 to 57 feet, 57 to 59 feet, 59 to 60.5 feet, 60.5 to 62 feet, and 62.5 to 64.5 feet BGS). Additional split-spoon samples were collected from 70 to 72 feet, 80 to 82 feet, and 90 to 92 feet BGS. The aquifer material was placed into a new, clean five-gallon bucket with a lid and kept cool (0 °C to 6 °C) until it was delivered to SGS for the testing. (The sample from 100 to 101.5 feet BGS in this boring was collected as an analytical sample for SGS; the sulfolane concentration result for this sample was less than the limit of quantitation of 0.613 mg/kg.)

Twenty liters of sulfolane-free groundwater from the NPR was collected from MW-173A and provided to SGS for use in the testing. The testing procedure was conducted in 12 half-gallon (1,900 milliliter [mL]) glass wide-mouth Mason jars with lids, into which were placed aquifer material and sulfolane-spiked groundwater from the NPR. A description of the testing protocol is provided below.

A 10-liter composite of aquifer sediment was prepared, and the free water was drained from it using paint filters or cheesecloth. From the composite, three subsamples were collected for determination of sediment-phase sulfolane concentration, bulk density, total organic carbon content, and moisture content. Aliquots of the remaining composited aquifer sediment were placed into the jars as outlined in the table below. Twenty liters of groundwater were spiked with 10 milligrams of sulfolane, and the remaining jar volumes were filled with sulfolane-spiked groundwater, leaving minimal headspace; the volume of water added to each jar was recorded.

Jar ID:	1, 2, 3	4, 5, 6	7, 8, 9	10, 11, 12
Sediment volume:	900	750	500	250
Water Volume	Balance (about 1,200 mL)	Balance (about 1,350 mL)	Balance (about 1,600 mL)	Balance (about 1,850 mL)

Once the sorption-testing jars were prepared, they were treated in the following manner:

- Shake the jars by hand for 90 seconds, then store at 2 °C to 6 °C.
- After 24 hours, filter the contents of Jars 1, 4, 7, and 10 through a 0.45-micron filter and analyze for sulfolane. Shake the remaining jars by hand for 90 seconds, and place back in cool storage.
- After 48 hours, filter the contents of Jars 2, 5, 8, and 11 through a 0.45-micron filter and analyze for sulfolane. Shake the remaining jars by hand for 90 seconds, and place back in cool storage.
- After 72 hours, filter the contents of Jars 3, 6, 9, and 12 through a 0.45-micron filter and analyze for sulfolane.

The data resulting from this testing, summarized in Section 3.9.2, included:

- Sulfolane and organic carbon concentrations measured on the triplicate sediment samples
- Bulk density (grams/mL) of the drained sediment
- Moisture content of the drained sediment
- Volume of water added to each test jar
- Sulfolane concentrations at the specified equilibration times for each jar

These data are used to estimate a distribution coefficient (K_d , K_{oc}) for sulfolane in NPR aquifer material. The distribution coefficient can be used to estimate the amount of sulfolane adsorbed to the aquifer material at a given groundwater concentration, and can be compared to published values to evaluate the degree of adsorption relative to that observed at other sites.

2.6.4 Data Evaluation

The SCWP proposed to evaluate groundwater analytical data in order to identify trends. Trend data assist in the evaluation of plume migration, stability, remediation effectiveness, and the correlation of data to water table fluctuations. A preliminary analysis of the temporal variability in sulfolane, BTEX, and 1,2,4-TMB groundwater concentrations in the area of NPR was undertaken using a statistical analysis of historical groundwater data.

As stated in Section 6.7.1.3 of the SCWP, Monitoring and Remediation Optimization System (MAROS) software developed by the Air Force Center for Engineering and the Environment (AFCEE) was to be used to evaluate concentration trends with the program's Mann-Kendall test module. However, MAROS is unable to handle data sets with greater than 40 results. Since many of the wells have data from greater than 40 sampling events, SWI developed a computer program capable of performing the Mann-Kendall test and calculating the data set's coefficient of variation (COV) to assess temporal trends when the number of observations is greater than 40.

The MAROS evaluation of concentration trends depends on the result of a Mann-Kendall trend analysis, coupled with the COV. A statistically significant increasing or decreasing trend will be identified by the Mann-Kendall analysis if the probability of a false-negative assessment is less than 5 percent (i.e., $p < 0.05$); MAROS refers to this condition as a "confidence in trend" above 95 percent.

MAROS purports to discriminate between "no trend" and a "stable" contaminant concentration by evaluating the COV of a given well's data set. The COV is defined as the ratio of a data set's standard deviation to its mean. COV values less than or near 1 indicate the data form a relatively close group about the mean value; values larger than 1 indicate the data exhibit a greater degree of scatter about the mean. The MAROS decision matrix is tabulated below:

Mann-Kendall Statistic	Confidence In Trend	Concentration Trend
$S > 0$	> 95 percent	Increasing
$S > 0$	90 to 95 percent	Probably Increasing
$S > 0$	< 90 percent	No Trend
$S \leq 0$	< 90 percent and $COV \geq 1$	No Trend
$S \leq 0$	< 90 percent and $COV < 1$	Stable

S < 0	90 to 95 percent	Probably Decreasing
S < 0	> 95 percent	Decreasing

The MAROS trend evaluation results for the wells in the NPR monitoring network are presented in Sections 3.8.6 and 3.8.8. Only those wells with greater than three sampling events (the minimum for any statistical test) were considered. In addition, only sampling results from 2006 to the present were used to be able to compare data with similar detection limits. For the statistical analyses, nondetect results were represented numerically by a zero rather than a value equal to one-half of the practical quantitation limit as stated in the SCWP, to avoid false positive identification of trends related to perturbations in the PQLs.

It is important to note that this statistical analysis is limited to the database utilized and is subject to the limitations that are inherent in conducting this type of analysis at this time. The program does not consider or interpret other site conditions such as seasonal fluctuations and monitoring well functions. In addition, many of the sampling locations have not been sampled during a full year of water table fluctuations. These factors will be evaluated by the project team and, as such, data evaluation will continue as data are gathered.

2.7 Gravel Pit and Surface Water Sampling and Analysis

On August 11, 2010, surface water samples were collected from the north and south gravel pits, as specified in the SCWP (Figure 13). The SCWP also indicated FHRA would complete gravel pit sampling at an additional downgradient location, immediately south of monitoring well nest MW-160. However, due to concerns regarding contamination from nearby surface use impacting water quality in the gravel, thereby impacting ability to collect samples representative of groundwater entering the pit, the pit was not sampled.

An additional surface water sample was collected from Badger Slough, north of the extension of Garnet Drive on October 10, 2010 (Figure 13).

The gravel pit samples were collected by dipping a clean sample jar attached to a pole in the water approximately 10 feet from the shoreline. The slough sample was collected by using a disposable bailer and filling the required analytical sample jars. Each of the samples was recovered from within eight inches of the water's surface, in accordance with the SAP. The samples were submitted to SGS for analysis of sulfolane by USEPA Method SW8270D. Results are discussed in Section 3.11. Laboratory reports are provided in Appendix M.

2.8 Monitor Effectiveness of IRAP Corrective Measures

During the first quarter of 2011, samples for laboratory analysis were collected on a monthly basis from the groundwater treatment system discharge (referred to as the Gallery Pond effluent) in accordance with Wastewater Disposal Permit 2005-DB0012. Additional samples were collected to gauge performance of the treatment system at the combined air stripper influent and active air stripper effluents (Towers C and D). Results of this monitoring are presented and discussed in Section 5.1.2.

Samples were collected into the appropriate laboratory-provided sampling containers. Samples were then submitted to SGS for determination PAH by USEPA Method 625 and BTEX by USEPA Method 624. In addition, the combined air stripper influent and gallery pond effluent was submitted for the determination of sulfolane by USEPA Method 8270D.

In accordance with the sampling requirements outlined in the IRAP, additional monthly sampling will be initiated in the second quarter of 2011 upon completion of the granular activated carbon (GAC) filtration system. In addition to the current monitoring locations, monitoring will also be conducted at the outlet of the GAC system. A description of the GAC system and enhancements to the existing remediation system is provided in Section 5. In addition to sulfolane and BTEX, the samples will also be analyzed for 1,2,4-TMB, pH, alkalinity, TOC, dissolved iron, total aromatic hydrocarbons (TAH), and total aqueous hydrocarbons (TAqH), in accordance with Section 6.10 of the SCWP and Section 4.3 of the IRAP.

In accordance with the requirements of the Wastewater Disposal Permit, samples will be collected from MW-106 and MW-141 in April 2011 and September 2011 (semiannually) with analysis for BTEX and TAH. The results of the April monitoring will be presented in the second quarter monitoring report.

3.0 Results and Findings

This section presents the results of data collected through the first quarter of 2011 during site characterization, including all groundwater monitoring data that would otherwise be presented in a quarterly monitoring report. Also presented are results of the laboratory drain investigation and a summary of the sump investigation results previously submitted to ADEC.

3.1 Sources and Release Mechanisms

3.1.1 Potential Sources of Contamination

Potential sources of contamination include product storage tanks; USTs; product distribution systems including the truck-loading racks and railcar-loading areas; the process areas including CUs #1, #2, and #3 and the extraction unit (EU); the wastewater system, including the wastewater lagoons, sumps and drain systems; drum storage areas; waste piles; and septic systems. Of these areas, sulfolane was present or potentially present in the sulfolane storage tank (Tank 194); Tanks 192, 195, and 196; the railcar and new truck-loading rack, the EU, and the wastewater lagoons, sumps and drain systems. Further evaluation of each area is discussed below.

3.1.1.1 Sulfolane Use

The sulfolane extraction process was added to NPR in 1985. Sulfolane solvent has been received at the site via railcar and tanker trucks and is off-loaded to Tank 194. Tank 194 is located at the southwestern portion of the developed site southwest of CU #1 (Figure 3). Sulfolane is delivered to the EU (Figure 3) via aboveground piping as indicated in the EU process flow diagram (Appendix C of the SCWP). Sulfolane is used in the EU to extract aromatics in the process of making gasoline from crude stock. Aromatics are then stripped from the sulfolane and the sulfolane is recirculated and reused in the extraction process.

3.1.1.2 Product Storage Tanks

The product storage tanks are located in the central portion of the site (Figure 3) and they are all constructed within bermed and lined containment areas, but, because they store product and, historically sometimes wastewater, there is a potential for releases to the subsurface in these areas.

In particular, historical records indicate that Tanks 508 and 509 (the bolted tanks) leaked, as did their containment area, indicating that they were potential sources of releases to groundwater at the site. Tanks 508 and 509 were 10,000-barrel bolted steel, repurposed military tanks located near the south end of containment area CA5 (Figure 3). These tanks were used to store hydrocarbon product until

1986, at which point they were decommissioned. The tanks were then used to provide extra storage and treatment capacity for wastewater when Lagoon B was full, as discussed below in Section 3.1.1.6. Aerial photographs indicate that these tanks were removed sometime between 1993 and 1995.

These tanks have been reported in several facility records to have leaked fuel products. The containment area around Tanks 508 and 509, although lined, was reported to have leaked due to holes punctured in the liner during construction. Free product is present under the tank farm area, directly to the north of the former location of these tanks. It does not appear that Tanks 508 and 509 would have been material sources of sulfolane to groundwater because a majority of the releases from these tanks predated sulfolane use at the site and the tanks were reportedly lined prior to their use in wastewater treatment activities.

Analysis of LNAPL samples collected from wells located in this area has been completed and the preliminary data, specifically from recovery well R-32, confirm that sulfolane is not present in the LNAPL in this area. These results are discussed further in Section 3.7.4.

3.1.1.3 Underground Storage Tanks

Five USTs are located at the site (Figure 14) as follows:

- 1,000-gallon steel heating oil tank at Administration Building
- 4,000-gallon steel heating oil tank at Maintenance Building
- 1,500-gallon steel heating oil tank at Warehouse/Operations Building
- 1,000-gallon steel heating oil tank at Security Building
- 1,000-gallon steel heating oil tank at Laboratory Building

All USTs undergo annual leak and tightness testing and are protected from corrosion by deep bed anode systems.

Sulfolane is not anticipated to be present in the fuels stored in the USTs, as they store heating oil and sulfolane is used to produce gasoline. During the onsite soil investigation described in Section 8.1, soil borings will be placed near the USTs to investigate potential releases of heating oil.

3.1.1.4 Product Distribution Systems

3.1.1.4.1 Railcar-Loading Area

The railcar-loading area is located in the northwest portion of the refinery (Figure 3). Historical spills to soil in the railcar-loading area have been reported in numerous documents and spill records. Spills to the soil were reportedly more common prior to 1985 due to the limited catchment basins at the railcar-loading rack that were not as long or as wide as the railcars, and would have allowed spilled product to escape to soils. The original catchment basins for the railcar-loading area were initially modified during the refinery expansion in 1985 to cover the entire length of the railcars. The spill containment system at the railcar-loading area was once again modified to be wider than the railcars in 1996. Currently, the railcar-loading area is configured with catchment pans between and along the sides of the rails.

While petroleum impacts are present in this area (see Section 3.6.1), sulfolane impacts are not expected. Railcars that were historically used to deliver sulfolane were offloaded at the southern portion of the rail spur, near Tank 194. In addition, fuel products that are loaded into railcars at the rail rack that had come in contact with the sulfolane extraction process could have potentially contained residual sulfolane due to “carryover.” However, the “carryover” sulfolane concentration in any spills of fuel products to soil at the site would be nominal when compared to the concentrations of sulfolane measured in wastewater.

If this area is accessible, it will be investigated during the soil investigation described in Section 8.1.

3.1.1.4.2 Truck-Loading Racks

The former truck-loading rack was located just east of the railcar-loading area (Figure 3). It was constructed on a concrete pad; however, it is not known if there was containment for the concrete pad area. The former truck-loading rack was decommissioned as part of the 1985 refinery expansion prior to the inception of sulfolane use at NPR. At that time, a new truck-loading rack was constructed at the north end of the refinery (Figure 3).

The new truck-loading rack was built on a concrete pad with a containment curb around the outside of the pad, and the entire area slopes toward a sump containment system. Therefore, uncontained releases from this area are unlikely and contributions to the subsurface are not expected to have occurred from this area due to the presence of the containment system from inception of use.

Analysis of LNAPL collected from an observation well located in this area (S-51) is discussed in Section 3.7.4. Results indicate that sulfolane is not present in the LNAPL in this area.

3.1.1.5 Process Area

The process area consists of CU #1, CU #2, CU #3 and the Extraction Unit, which are located in the southern portion of the site, south of the tank farms (Figure 3). Of the process areas, sulfolane is used in the EU, which is adjacent to CU #2. Further description of the process area, with respect to sulfolane in wastewater and sumps, is discussed below. Releases are described in Section 3.1.2.

During the onsite soil investigation described in Section 8.1, soil borings will be placed near the process area to investigate known and potential releases.

3.1.1.6 Wastewater System

The site is currently configured with three lagoons (Lagoons A, B, and C; Figure 3). Lagoons A and C are currently in operation for storage and treatment of wastewater. Lagoon B, which was decommissioned in 2006, was the only wastewater lagoon onsite between 1977 and 1987. Lagoons A and C were built in October 1987 and September 1989, respectively.

Prior to October 1987, some wastewater was sent from Tank 192 to CU #1 for evaporation; the remainder was then sent to Lagoon B. Tank 192 was installed during construction of the refinery in 1977, at the west end of CU #1 (Figure 3). The tank was used to collect material, including storm water runoff from the oily water sewer system. Tank 192 separated the hydrocarbon and water fractions; hydrocarbons were returned to the refining process and wastewater was sent to treatment or vaporization. Before October 1987, what is now known as Lagoon B was the only lagoon in the wastewater treatment system.

Once Lagoon A was constructed in October 1987, Lagoon B received aerated wastewater from Lagoon A through September 1989, when Lagoon C was constructed. Wastewater in Lagoon A was aerated for ~18.5 days (summer operations), after which the wastewater was sent to Lagoon B, where it would reside for ~28.5 days (summer operations). The effluent from Lagoon B would then drain to Sump-909A, and from there it was pumped to the city sewer.

In 1998, the wastewater treatment system was upgraded to handle the additional water that would be introduced to the system with the construction of CU #3. The upgrade consisted of the installation of additional air strippers, the CTX-40T box unit (CTX boxes) and piping to accommodate parallel flow between the CTX system and air strippers, as well as repair of corroded piping between Lagoon B and the city sewer system.

As noted previously, Tanks 508 and 509 (i.e., the Bolted Tanks) were also used for the storage and treatment of wastewater after they were taken out of service for product storage in 1986. Reportedly, the Bolted Tanks were used when Lagoon B was full and the refinery required storage of additional out-of-spec (e.g., high sulfolane, biological oxygen demand/chemical oxygen demand [BOD/COD]) wastewater before treatment.

Tanks 195 and 196 were constructed in 2003 and are currently used as buffer tanks for potentially out-of-spec wastewater; process water from sources that may contain sulfolane is diverted to these tanks prior to flowing to Tank 192 and metered into the system when treatment system conditions permit.

Sulfolane from the EU has been introduced into the wastewater system. Historical records reflect that sulfolane has been measured in wastewater at the refinery and has been found and monitored in many portions of the wastewater system. Therefore, releases of wastewater to the subsurface may have included sulfolane.

Historical wastewater records indicate that sulfolane in wastewater has been measured at levels exceeding 1,000 ppm. General process knowledge indicates that sulfolane-containing wastewater has been introduced to Sump 02/04-2, and historical data indicates the presence of sulfolane in Lagoon B, Sump 908, and Tank 192, and more recently in Tanks 195 and 196. Additional discussion of Sump 02/04-2 follows in Section 3.1.1.6.2.

3.1.1.6.1 Wastewater Lagoons

Records for Lagoons A and C indicate that both lagoons were constructed as a double-lined system with leak detection. Lagoon A records from 1988, 1991, 1996, and 1997 indicate that there were integrity issues with the liner system in this lagoon. Records for Lagoon C indicate that there had been liner integrity issues prior to 2000 in this lagoon. The records are unclear as to whether significant releases were associated with the liner integrity issues. General process knowledge and data from Tank 192 indicates the possibility that sulfolane may have been included in wastewater stored in Lagoons A and C.

Historical records indicate that there have been liner integrity problems with Lagoon B that have resulted in sulfolane releases that have impacted groundwater, as indicated by data collected from adjacent groundwater monitoring well MW-110. Lagoon B was reported to have been removed from active service and replaced by Lagoon C in September 1989. However, aerial photographs indicate that liquid was still present in Lagoon B soon after Lagoon C was introduced to the wastewater

treatment system in 1990 and 1991. The wastewater held in Lagoon B was pumped into Lagoon C starting on May 22, 1991, continuing throughout the month.

Closure operations for Lagoon B began in 1990 but were not completed until July 1991, at which time the liner was removed. A closure certification report was provided to the USEPA. Photos taken during inspection of the lagoon showed holes in the liner.

After closure operations were completed at Lagoon B in 1991, the liner was replaced and use of the lagoon was reserved for out-of-spec (i.e., high sulfolane or BOD/COD) wastewater until FHRA emptied the lagoon in 2006. Records and aerial photographs indicate that water resided in Lagoon B throughout much of that time period.

Records indicate that holes in the lagoon were initially identified in 1986 and again in 1990 and 1991. When FHRA emptied the lagoon in 2006, additional holes and tears were found. Historical records indicate that high-sulfolane concentration wastewater was stored in Lagoon B prior to 2003, and groundwater data collected from MW-110 indicate that Lagoon B was a historical source of sulfolane to groundwater.

3.1.1.6.2 Sump and Drain Systems

The facility's oily water sewer system collects water from the process areas, tank farms, skid runoff, laboratory, truck rack and railcar-loading area catchment basins, the sump and drain system, and the equipment-loading area.

The sumps, constructed as part of the original refinery, were made of concrete. Because containment issues were observed in the concrete sumps, the sumps were lined with steel during the 1984-1986 timeframe. Additional sumps were constructed on an as-needed basis as additional facilities were added to the refinery (Appendix H). The sumps and drains are underground structures at the site, and there is a potential for leaks from the sumps and drains to the subsurface under the site.

In 2009 and 2010, FHRA undertook a comprehensive evaluation of the integrity of the sump and drain systems at the refinery. The results of this investigation were reported to the Alaska ADEC by FHRA in a letter dated December 8, 2010 (Appendix H). Integrity issues were identified for five of the 42 refinery sump systems. These five sumps were potential sources of releases to the subsurface. However, three of the five sumps found to have integrity issues would not have come in contact with sulfolane during operation, and all of the five sumps were repaired by FHRA. Also, the inner shell of Sump 02/04-2, which would have been the recipient of material containing sulfolane, was not found

to have integrity issues during this inspection; however, it was discovered that a 1997 repair of the sump did not provide for a weld around a pipe penetration in the shell. The drain lines from CU #2 into the sump were found to have integrity issues.

FHRA issued a separate report on July 21, 2010 relating to integrity issues identified with the laboratory drain system (Appendix G). The results of investigations completed at specific sumps are discussed further in Section 3.6.4.

Evidence of Historical Releases from Sump 02/04-2

Sump 02/04-2 is located between CU #2 and the EU (Figure 3) and acts as a collection point for both units, connected to both by a drain system. It is also used to collect residual draindown and wash water during EU turnarounds (maintenance events).

Turnarounds for the EU required de-inventorying of process tanks within the unit by transferring sulfolane-containing fluids to tanks or railcars on the facility property. After the process tanks were de-inventoried, the residual material and the wash water were allowed to gravity-drain to sump 02/04-2. EU turnarounds occurred every year or every other year from 1985 (when the unit was constructed) until 2003, then again in 2006 and 2010.

Sump 02/04-2 appears to have been a source of sulfolane to groundwater, based on sump integrity records and the groundwater chemistry from downgradient monitoring well MW-138. Integrity issues were identified during a November 3, 1997 inspection that found that the bottom of the sump had corroded through. Following that inspection, the operator at the time installed a new steel liner in the sump. A May 19, 2009 inspection revealed that a gasket for a nozzle in the sump had deteriorated and that no back-weld had been completed during the 1997 repair. Also during the 2009 inspection, drain lines coming from CU #2 into Sump 02/04-2 failed a leak test.

During the onsite soil investigation described in Section 8.1, soil borings will be placed near the areas discussed above to investigate potential impacts.

3.1.1.7 Drum Storage

Drums and portable containers are stored in the following areas (Figure 3):

- CU #1 – 400-gallon oil cleaner
- CU #2 – 400-gallon oil cleaner

- CU #3 – 3,400-gallon filming amine storage tank
- CU #3 Utility Building – 55-gallon used oil drums, 110-gallon compressor oil drums
- Effluent Building – 400-gallon filming amine storage tank; 6,000-gallon demulsifier storage tank; 450-gallon lube oil tote
- Maintenance Building – 120-gallon kerosene skid mounted storage tank
- Chemical Injection Room – 330-gallon monoethanolamine totes, 165-gallon lube oil drums, 55-gallon antifoam drums
- Warehouse Skid Curbed Containment Area – up to 21,120 gallons (motor oils, octane reference fuels, seal fluids drums and totes)
- Hazardous Waste Storage Containment Area – up to 18,040 gallons in used oil drums

The volumes listed for the drums are based on maximum number of drums that could be onsite and, therefore, may not be an accurate representation of actual volumes at a given time.

During the onsite soil investigation described in Section 8.1, soil borings will be placed near the areas listed above to investigate potential releases.

3.1.1.8 Waste Piles

A contaminated soil storage skid (40' x 20' x 3.5') located in the hazardous waste storage area (Figure 3) is used to store propylene glycol or non-benzene containing hydrocarbon-impacted materials. Soils are covered by polyethylene liner material after each addition prior to shipment offsite for treatment and/or disposal.

On occasion, excavated contaminated soils have been stored in the open area northeast of the laboratory (Figure 14) on visqueen until they are profiled. These waste piles are covered to eliminate potential leaching of contaminants to the ground due to precipitation. Once the soil has been sampled, it is placed in roll-off boxes until characterization is completed and the soils are then sent offsite for treatment and/or disposal. During the onsite soil investigation described in Section 8.1 soil borings will be placed near the areas listed above to investigate potential releases.

3.1.1.9 Septic Systems

A septic system and leach field with a conventional soil absorption system is located east of the Distribution facility and west of Tank 401 (Figure 14). The tank was replaced on August 30, 2001. Additional leach fields are present at the laboratory and near the truck-loading rack (Figure 14).

Based on review of the EU PFD, sulfolane is not anticipated to be present in the septic system.

3.1.2 Spill Events and Releases

Spill records from NPR do not reflect all of the material historically spilled, as evidenced in reports from the 1980s that indicate the recovery of substantially more product than had been documented as releases. Spill records also do not reflect releases that may have occurred from below-grade structures, particularly including the oily water sewer system and lagoons.

3.1.2.1 Volume Released

The MAPCO 90-Day Response (1989) indicated that 92 spills were reported between 1977 and 1987, resulting in more than 160,000 gallons leaked or spilled at the site. However, it was also represented in the same report that 275,000 gallons of product were recovered, suggesting that considerably more product had been recovered than was reportedly spilled.

A total of 3,096 documented spills have been reviewed from 1977 to 2010. From those records, 2,863 of the spills included volume estimates. The total volume of the documented spills was ~281,964 gallons.

3.1.2.2 Release Location

Records reflect spills in numerous locations throughout the site. These locations include the process areas (CUs #1, #2, #3, and the EU), the area of the lagoons, product storage areas (e.g., tank farms), the railcar-loading rack area, and the current and former truck-loading rack areas (Figure 3).

3.1.2.3 Spill Response Remediation Performed

The spill records reflect that, in many cases, efforts were made to recover at least a portion of the material that had been spilled. During the winter, remediation efforts typically involved allowing the material to freeze, at which point it was collected and disposed of. During the warmer months, spills onto soil or gravel were generally excavated. Sorbent pads were commonly used if the spill was on an impermeable surface. Material that was released to skids was often washed to a sump and allowed to enter the oily water system.

3.1.2.4 Confirmation Sampling

A majority of the spill records do not reflect that confirmation sampling was completed to verify the adequacy of remediation efforts. Due to the presence of historically-spilled petroleum hydrocarbon already present in the soil, confirmation sampling may not have been completed in many instances because of perceived difficulty of distinguishing current spills from historic spills.

3.1.2.5 Summary

Due to the large number of historical releases and the lack of information regarding specific cleanup actions and soil sampling, a data need exists regarding soil quality. A soil investigation (described in Section 8.1) will be performed in 2011 to fill this need.

3.1.3 Potential for Ongoing Release

The potential for ongoing releases is mitigated by FHRA through its integrity and inspection program and its active awareness program. In addition, ongoing groundwater monitoring provides additional data regarding potential ongoing releases.

3.1.3.1 FHRA Programs

FHRA has taken a two-pronged approach for the prevention of future releases at NPR. The first is through prevention of spills and leaks, and the second is through mitigating a leak before it causes a significant environmental impact. The preventative strategy is completed through the mechanical integrity programs for storage tanks, sumps, ponds, and underground piping from certified inspectors, as well as more frequent inspections by operators. The mitigation strategy is completed through a very active awareness of leak potentials and quick responsiveness to spills. More details are listed below.

3.1.3.1.1 Mechanical Integrity and Inspection Program

The mechanical integrity and inspection program spans four major areas for the mitigation of future contaminant releases which include tanks (feed and storage), wastewater sumps, wastewater lagoons, and piping.

- Tanks: All storage tanks are inspected on a rotation consistent with API 653. Inspection results and repairs are documented in the Equipment Files.
- Wastewater Sumps: FHRA has 42 sumps that were all inspected in 2009 or 2010. Inspection records and repairs are documented in the Equipment Files. Future inspection frequencies have been set based on a risk assessment of service, historic corrosion, and past repairs. As

part of the sump inspections FHRA has tested the underground piping feeding the sump systems. Any lines that were suspect for leakage have been removed from service. FHRA is evaluating alternatives for repairing, replacing, or leaving out of service the affected piping. Results of the sump investigation are discussed in Section 3.6.4.

- **Wastewater Lagoons:** The wastewater system has two lagoons (A and C) which have liners that have two liners with leak detection between the primary and secondary liners. The primary liner is installed on the surface of the ground. The secondary liners are externally inspected each spring. The manufacturer's end of life for the liners is typically in the range of 15 to 20 years, but the inspections determine the extent of patch repairs or replacement. A third lagoon (B) is out of service, as discussed previously.
- **Piping:** The piping mechanical integrity program involves a methodical routine of thickness testing and tracking in a database. Corrosion rates are tracked and retirement dates are projected. FHRA proactively repairs or replaces piping prior to retirement dates.

3.1.3.1.2 Active Awareness Program

NPR has very stringent protocols and expectations regarding the mitigation, awareness, reporting, and responses to releases. The operating personnel have an ongoing active awareness through routine surveillance rounds to locate spills before they become an impact or attempt to minimize the release by early detection. Supervisor Incident Reports (SIRs) are used to document any plant spills (no matter how minor) as they occur, usually by operating and maintenance personnel. The SIR is submitted to the Refinery Shift Superintendant and investigations and applicable cleanup activities are initiated immediately.

In addition, the supervisory and management personnel conduct multiple audits throughout each month regarding safety, environmental cleanliness, and housekeeping for each unit. These audits have a report structure and are logged, and both are used to provide information back to operations.

3.1.3.1.3 Summary

FHRA prevents spills by the use of the mechanical integrity and inspection programs. The refinery personnel are engaged in spill prevention and providing rapid cleanup response to spills.

3.1.3.2 Groundwater Monitoring

Since the comprehensive LNAPL monitoring network has been employed for a short period of time, and a few LNAPL analyses have been completed, more data need to be collected to determine

whether the data suggest any ongoing release that has not been detected and resolved in the course of FHRA's mechanical integrity and active awareness programs. Dissolved-phase trend data are discussed in Sections 3.8.6 and 3.8.8. Preliminary evaluation suggests stable or decreasing trends in the groundwater COPCs at most locations, which would indicate that an ongoing release is not occurring. Monitoring of LNAPL and dissolved-phase constituents will continue, as discussed in Sections 8.3, 8.4 and 8.5.

It should be noted that most of the potential sources of significant releases (i.e., product storage tanks and process areas) are within the capture zone of the groundwater pump and treat system.

3.1.4 Potential Offsite Sulfolane Sources

Site summaries from the ADEC contaminated sites website and from SWI's project files are presented in Table 8 and shown on Figure 15. To date, the higher priority has been placed on delineating the offsite plume rather than identify other potential offsite sources; therefore, evaluation of the sites with respect to the offsite plume has not been completed. As offsite sulfolane data are gathered, potential anomalies will be compared to known contaminated sites to evaluate those sites as sources; however, as described in Section 3.1.1.4.1, "carryover" of sulfolane into fuel products is not believed to be a significant source of contamination.

3.2 Contaminants of Concern

Historical operations at the refinery included crude oil processing. Petroleum hydrocarbons are the primary constituents associated with these activities. Historical site investigations have indicated that various materials associated with the refining process have been released in portions of the site, particularly in areas of storage and transfer, such as the CUs, tank farms, and loading racks. COIs were identified from a list provided by the refinery laboratory in January 2011 of possible "ingredients" of historical material spilled at the site. COI concentrations detected during historical groundwater monitoring, and the soil concentrations observed during the 2000-2001 and the 2009-2010 site investigations were considered during this evaluation.

Table 9 presents COIs in soil and groundwater at the site reported by information source. Also included in the table, for each COI, an indication (demarcated by an "X") is noted if specific toxicity values are available in the USEPA 2011 Integrated Risk Information System (IRIS).

Table 10 presents the COPCs identified in soil and groundwater based on application of ADEC (2010) COPC selection guidance to the identified COIs. Maximum detected concentrations and/or the PQLs of COIs in soil and groundwater were compared with ADEC screening levels. COI soil

concentrations were compared with ADEC (2010) screening levels protective of potential migration to groundwater based on a zone with less than 40 inches of annual precipitation (ADEC, 2008a; Table B1, Method Two). If ADEC soil screening levels were unavailable, then constituent concentrations in soil were compared with USEPA (2010) Regional Screening Levels (RSLs) based on potential migration to groundwater. Soil screening levels for GRO, DRO, and RRO were from ADEC (2008a) Table B2 Method Two. COI groundwater concentrations were compared with ADEC groundwater screening levels (ADEC 2008a; Table C). If ADEC groundwater screening levels were unavailable, then constituent concentrations were compared with USEPA RSLs based on tap water ingestion. Those COIs with maximum concentrations or PQLs (when all samples were nondetect) exceeding applicable ADEC screening levels were identified as COPCs.

Although arsenic is listed as a COPC based on the ADEC screening level comparison, the maximum detected concentration in soil of 5.42 milligrams per kilogram (mg/kg) does not exceed a site-specific background concentration in soil of 14.46 mg/kg, as reported by SWI (2001) and developed by the Alaska District U.S. Army Corps of Engineers (USACOE) based on soil data collected in the area of Fort Wainwright, Alaska. Copper, iron, nickel, zinc, silica and sulfolane were not analyzed in soil during the Characterization Studies; however, they were considered possible ingredients of materials spilled at the site. Thus, although it is unlikely that copper, iron, nickel, and zinc were used during crude oil processing, they may be considered COPCs in soil and groundwater. Silica is unlikely to be a COPC in groundwater as it is only toxic by the inhalation route and silica in groundwater is not respirable.

Also included in Table 10 are eight chemicals for which there are no toxicity levels established by USEPA in IRIS. Further research will be conducted to determine if independent toxicity evaluations have been conducted. The COPC list will be refined further based on these findings.

Table 11 shows a list of COIs that are not considered to be COPCs in soil and groundwater. Either they are a type of clay, are ubiquitous in natural water, or are a petroleum distillate mixture composed of several individual substances.

In summary, the COPCs identified at the site, as presented in Table 10, are those COIs that were detected in site media and exceeded conservative ADEC screening levels, COIs not detected in site media but their PQLs exceeded ADEC screening levels, and COIs identified by the refinery laboratory as “ingredients” that could have been released and, therefore, are considered potential COPCs. Constituents without available USEPA toxicity values, with the exception of sulfolane, and

metals detected in site media at concentrations within the range of site-specific background concentrations were not selected as COPCs.

3.3 Geology

NPR and the surrounding North Pole area are located on a relatively flat-lying alluvial plain that is situated between the Tanana and Chena Rivers. The Tanana is a braided river and, as such, exhibits an anastomosing pattern of channels separated by bars and islands. NPR is located on the Tanana River Floodplain (Figure 1).

The geology of the area is dominated by a thick sequence of unconsolidated alluvial deposits. Depth to bedrock has been estimated at 400 to 600 feet. An injection well on the GVEA property adjacent to NPR (Figure 3) was drilled to a depth of 450 feet and did not encounter bedrock, and no borings placed during site characterization have encountered bedrock.

Using information from boring logs (Appendix B), several cross sections have been prepared to show the stratigraphy in the upper 100 feet of the alluvial deposits. Four cross sections have been prepared showing NPR and the downgradient offsite area at the locations shown on Figure 16. These four cross sections are shown on Figures 17 through 20. Two additional cross sections have been prepared to show the onsite geology at the locations shown on Figure 21. The two cross sections are shown on Figures 22 and 23.

Up to two feet of organic soils can be found in the undeveloped portions of the NPR property and surrounding area. As properties are developed, the organic soils are often removed prior to construction and replaced with fill. As shown on the cross sections, boring logs indicate that fill is present at a few onsite and offsite locations at depths of up to 6 feet BGS. The fill is typically compacted sand and gravel likely derived from local sources.

The cross sections show discontinuous layers of silt, fine sandy silt, and silty fine sand, with occasional peat lenses have been encountered in the upper 10 feet of the unconsolidated sequence. Color of these deposits varied considerably from black to brown to gray, occasionally exhibiting gray and brown mottling near the water table. The silty soils vary in thickness from 0 to 10 feet and are believed to have been deposited in sloughs and meander-cutoff channels. Historical topographic maps and aerial photographs predating NPR construction show a slough and meander loop in the vicinity of the current truck-loading area and silty deposits were subsequently encountered during construction of the current truck-loading rack. Due to the braided nature of the Tanana, it is likely

that additional discontinuous silty deposits are scattered throughout the formation. As is the case with the organic soils, the silty layers are often excavated from properties during site development.

The GPR survey identified the depth of the contact between the fine silty deposits and the coarse sand and gravel deposits. A map showing these depths is included in Appendix D. Also included in Appendix D is a map showing the approximate boundary of the contact between the fine-grained silts and the coarse-grained sands and gravels at the water table. Since these data conflict with boring log information, they have not been added to the cross sections. A soil investigation, described in Section 8.1, will be used to confirm the results of the GPR survey. At that time, the cross sections will be updated with the silty layers.

Alluvial sand and gravel associated with the Tanana River are present below the organic soils and silty layers (Figures 17 through 20, 22, and 23). These alluvial deposits have been characterized as sandy gravels and gravelly sands, with occasional discontinuous lenses of sand, silt, and organic deposits. Peat was encountered at the MW-170 well nest from approximately 8 to 12 feet BGS and 20 to 21 feet BGS. Sands within these deposits were fine- to coarse-grained and gravel up to three inches in diameter was encountered. Color varied from brown to gray, although, as grain size increased, colors became dominated by the lithology of the clasts. These coarse-grained alluvial deposits are typically encountered within 12 feet of the ground surface and may extend to the upper bedrock surface.

3.4 Permafrost

3.4.1 Areas of Occurrence

Permafrost was encountered in sixteen of the monitoring well borings and reportedly encountered in private well borings installed in the vicinity of NPR. It should be noted that these private wells were installed between 1978 and 2005, and the permafrost conditions may have changed since the wells were installed.

3.4.2 Depth and Thickness

Top-of-permafrost depths ranged from 33 feet to 150.5 feet BGS in the monitoring well borings. No monitoring well borings have penetrated the permafrost.

Private well logs from unverified sources have reported that the top of permafrost encountered ranged from the three feet to 65 feet BGS. The bottom of permafrost ranged from 14 to 245 feet BGS. The thickness of permafrost layer was reported to range from five feet to 232 feet.

Figure 24 provides a graphical representation of the depth to permafrost in the area downgradient of NPR. It appears that permafrost was encountered in wells at shallower depths in areas farther northwest of the refinery, especially in the area along Peridot Street between Richardson Highway and Badger Road. The upper surface of the permafrost appears to be deepest at NPR, and also at well borings placed near Badger Slough. A “valley” in the upper surface of the permafrost appears to extend northwest from NPR, generally following Old Richardson Highway the Alaska Railroad.

Permafrost thicknesses from private well logs are shown on Figure 25. The thickest measurements were reported between Old Richardson Highway and Badger Road, west of Peridot Street.

3.4.3 Classification

The permafrost generally lacked visible ice and ranged from poorly- to well-bonded, with the exception of the MW-155B where visible ice was noted between sand grains. The descriptions of permafrost encountered during installation of the well borings are shown in Table 12.

The drillers that installed the private wells did not classify the permafrost beyond noting that subsurface materials were “frozen.”

3.5 Hydrogeology

Key hydrogeologic concepts include an understanding of sources and sinks of groundwater, the general distribution of conductive aquifer materials beneath the site and in the area, and the general distribution of permafrost and its influence on groundwater flow. For purposes of this discussion, “the site” is NPR property (Figure 2). Offsite includes areas in the vicinity of the site. Monitoring wells installed by FHRA beyond the limits of NPR are considered offsite.

Recharge to portions of the Tanana basin at elevations less than 1,000 feet MSL is estimated to be 8×10^6 acre-ft/yr (Anderson, 1970). Actual evapotranspiration over the same area is estimated to be 6.3×10^6 acre-ft/yr. The balance of the precipitation is believed to recharge the shallow water table, and then discharge to rivers within the basin. This portion of the basin has an area of approximately 12,000 mi². Therefore, the annual average rate of infiltration is approximately 2.7 inches per year (in/yr). This cycling of recharge to the area rivers occurs above the permafrost. Lakes and swamps in the basin act as sinks for groundwater when they are unfrozen.

3.5.1 Aquifer Characteristics

The aquifer beneath the alluvial plain between the Tanana and Chena Rivers was deposited by a high-energy, braided stream system (Nakanishi and Lilly, 1998, p. 4). The aquifer consists of a

complex system of alternating lenses of sand, gravel, and silt (Cederstrom, 1963, p. 17). The lenses are not known to be thick (typically less than 20 feet thick) and individual units cannot be traced for great distances in the subsurface (Cederstrom, 1963, p. 17; Nakanishi and Lilly, 1998, p. 4).

The aquifer beneath the alluvial plain between the Tanana and Chena Rivers generally consists of highly-transmissive sands and gravels under water table conditions (Cederstrom, 1963, p. 1; Glass, Lilly, and Meyer, 1996, p. 5). The Tanana River has a drainage area of approximately 20,000 square miles upstream of Fairbanks (Glass, Lilly, and Meyer, 1996, p. 5). In the vicinity of the NPR, this aquifer is reportedly greater than 600 feet thick (at least 616 feet near Moose Creek Dam: Glass, Lilly, and Meyer, 1996, p. 5); however, the deepest known well in the vicinity of NPR is the GVEA injection well, which is 450 feet deep and did not reach bedrock. This well is located at the GVEA substation along the southern NPR property boundary (Figure 3).

Reported hydraulic conductivities of the aquifer materials range from 8 to 2,400 feet per day (ft/day) (Nakanishi and Lilly, 1998, p. 6). These data are primarily from relatively shallow wells. However, the GVEA injection well, which is perforated from 412 to 432 feet BGS, had a specific capacity of approximately 80 gallons per minutes (gpm)/ft, indicating permeable materials were penetrated at that depth (Appendix E of the SCWP). Aquifer testing at NPR in 2009 indicated a hydraulic conductivity of approximately 130 ft/day based on pumping of wells penetrating the upper 15 feet of the aquifer (see Section 9.1.2 of the SCWP). Hydraulic conductivity estimated based on grain-size analyses for samples of aquifer material sampled during well installation range from 1.1 to 1,600 ft/day (Table 13). Aquifer testing of the new North Pole water supply wells in July 2010 indicated a hydraulic conductivity ranging from approximately 700 to 1,100 ft/day based on pumping of wells screened from approximately 120 to 150 feet below the water table (Barr, 2010c & Barr, 2010d).

In the SC/CAP, the gradient was estimated at 5.5 feet per mile and the groundwater velocity was calculated to be approximately 1.3 ft/day (SWI, 2002). Glass, Lilly, and Meyer (1996, p. 1) report a slope on the water table of 4 feet per mile.

These aquifer characteristics are consistent with results from other sites in the North Pole area, and historical literature. Slug test data collected in 1993 from the Arctic Surplus Salvage Yard site on Badger Road (8 miles northwest of NPR) yielded hydraulic conductivities ranging from 12 ft/day (silty sand, silt with sand, and gravel, 1.5 feet to 15 feet BGS) to 65 ft/day (gravelly sand, 50 feet to 60 feet BGS), and flow velocities up to 1.3 ft/day. A 1995 recovery well optimization study pump

test at NPR found variability in aquifer characteristics over small distances (i.e., tens of feet). The USGS reported the following range of hydraulic conductivities for various soil types (USGS, 1978):

Material	Hydraulic Conductivity (ft/day)
Silty Sand	0.01
Gravelly Sand	10
Sandy Gravel	100
Medium Gravel	10,000

3.5.2 Potentiometric Surface Elevation

The water table at NPR and offsite is shallow, typically occurring within 15 feet of the ground surface. Gravel pits excavated below the water table on the western portion of the site have filled with groundwater. The water table typically occurs within the alluvial sand and gravel although, in some cases, it may occur in the silty slough deposits.

Onsite the elevation of the water table varied from approximately 480 feet MSL to 490 feet MSL, decreasing from southeast to northwest. Offsite, the water table elevation varied from approximately 460 to 485 feet MSL, and decreases in elevation to the northwest, mimicking the gradually decreasing elevation of the ground surface (Figures 26, 27, and 28). The elevation of the potentiometric surface associated with deeper portions of the aquifer, as indicated by wells completed in the 15 to 55 feet below the water table interval is similar to the water table, as shown on Figure 29.

Figure 21 from the SC/CAP (Appendix J of the SCWP) indicates that the water table fluctuates, possibly up to nine feet (SWI, 2002). This is consistent with values reported by Glass, Lilly, and Meyer (1996, p. 13). Hydrographs for well MW-138 (Figure 31) and R-20 (Figure 32) show that the water table has fluctuated up to four feet since 2007. The groundwater elevation typically decreases during winter and early spring, with the lowest elevations occurring from late March through May. Elevations appear to increase during June and July, peaking during late July or August. Elevations then typically decrease through the remainder of the year (Figures 31 and 32). These variations are similar to those observed at three shallow wells maintained by the United States Geological Survey (USGS) as part of its Active Groundwater Level Network as shown as Appendix I of the SCWP.

Data from wells with pressure transducers and data loggers also confirm this pattern of fluctuation. The data from the MW-151 and MW-186 nests indicate increasing groundwater elevations in

December 2010, followed by decreasing elevations through March 2011. Groundwater elevations at the MW-170 nest increased during December 2010, decreased during January and February 2011, increased during early March, and were stable in later March. A limited data set (late February to mid-March) is available from the MW-162 nest, and groundwater elevations increased, in a manner similar to nest MW-170 during this time (Figures 32 through 35). Hydrographs from onsite observation wells, while not measured as frequently, show a similar pattern (Appendix N).

3.5.3 Flow Direction and Gradient

Beyond the zones of influence of the NPR groundwater recovery system, groundwater flow directions are controlled by discharge from the Tanana River to the aquifer and from the aquifer to Chena River, as described by Glass, Lilly, and Meyer (1996, p. 39). Variations in river stage over time are believed to be the primary cause of variations in flow direction through the aquifer between the rivers (for example, see Lilly, et al., 1996 and Nakanishi and Lilly, 1998, p. 4). Based on data from USGS water table wells, the flow direction varies up to 19° from a north-northwesterly direction to a few degrees east of north (see Appendix I of the SCWP). The flow direction trends to the north-northwest in spring and more northerly in the summer and fall (Glass, Lilly, and Meyer, 1996).

Data from the three USGS wells closest to the NPR indicate a slope on the water table ranging from 4.6 to 6.5 feet per mile. Data from the USGS Active Groundwater Level Network wells were included in Appendix I of the SCWP.

Flow directions are being monitored in the suprapermafrost aquifer north and west of the NPR. Data loggers have been deployed in fifteen wells and record water levels on a daily to hourly basis. The direction and magnitude of the hydraulic gradient in the aquifer can be estimated using groups of three wells completed at similar depths and arranged in a triangular pattern. Plots of the water level data and flow direction for seven combinations of the wells completed in the upper 10 feet of the suprapermafrost aquifer are shown on figures in Appendix E. The data loggers have been deployed for a relatively short period of time to date and the calculation is only possible when data are available from all three wells simultaneously. Based on this limited data set, the maximum observed variation in flow direction in the well network so far is just over 2 degrees and is much less in most of the well groups.

Groundwater elevation data from a period of high water table conditions during August 2009 were plotted on a site map and contoured (Figure 26). The map shows that the water table occurs at an

elevation between 484 and 489 feet above mean sea level (ft MSL). The contours indicate that the shallow groundwater flows in a north-northwesterly direction. The map also depicts localized depressions in the water table in the vicinity of the active recovery wells R-21, R35, R-39, and R-40.

Figure 27 shows a map of groundwater elevations measured manually in onsite and offsite water table wells on March 25, 2011. Figure 28 shows a map of groundwater elevations collected automatically using the transducers and data loggers in onsite and offsite water table wells on March 11, 2011. Both maps present data collected during a period of seasonally low water table elevations. Flow directions are more northwesterly at these times than during the period of higher water levels shown on Figure 26, which is consistent with the regional information described above. Once sufficient data are available to fully capture the variation on flow direction rose diagrams will be placed on the contour maps to depict the variation in flow direction.

The horizontal gradient in deeper portions of the aquifer, as indicated by wells completed in the 15 to 55 feet below the water table interval, also appears to be to in a northwesterly direction (Figure 29).

3.5.4 Vertical Gradients

Hydrographs have been prepared using data collected from automated loggers installed in well nests, including onsite nest MW-186, and offsite nests MW-151, MW-162, and MW-170 (Figures 32 to 35). The data are from the fourth quarter of 2010 and the first quarter of 2011.

At the MW-162, MW-170, and MW-186 well nests, groundwater elevations were always highest in the deeper wells, and lowest in the shallowest wells, indicating an upward vertical gradient. This was also the case from December 2010 through February 2011 at the MW-151 nest. However, in March, the groundwater elevation at the MW-151 nest was slightly (0.01 - 0.09 feet) higher in the water table well, indicating a downward vertical gradient (Figure 32).

3.5.5 Permafrost Influences

As stated above in Section 3.4, permafrost is believed to be absent beneath the Tanana River, Chena River, and Chena Slough. Discontinuity in the permafrost beneath the Tanana River was shown conceptually on Figure 13 of the SCWP. This is a critical factor in the hydrogeologic conceptual model because, as described above, these rivers are the primary sources and sinks for water in the aquifer.

As noted in the SCWP, the permafrost between the rivers is believed to be discontinuous. Residential wells logs in the North Pole area indicate maximum depths of permafrost ranging from 90 feet to 230

feet BGS. Many of the smaller-capacity water supply wells in the North Pole area and the new monitoring wells installed by NPR are completed above the top of the permafrost, in what is termed the suprapermafrost aquifer. Total depths of these wells range from less than 40 to 150.5 feet BGS. These shallow wells have been installed in the suprapermafrost aquifer because this aquifer does not completely freeze seasonally as it does in areas where the bottom of the suprapermafrost aquifer is closer to the surface and seasonal frost penetrates the aquifer.

Unfrozen aquifer material below the permafrost is termed the subpermafrost aquifer (e.g., Williams, 1970). Anecdotal information suggests the potential for an upward gradient between the subpermafrost and suprapermafrost aquifer. Groundwater quality measurements were collected from shallow and deep wells, as described in Section 2.3.4, and are discussed in Section 3.10.

Many authors indicate that permafrost is essentially impermeable (e.g., see Williams, 1970, pp. 1 and 24; Sloan and van Everdingen, 1988, p. 264). Bolton (2006, p. 49) indicates that permafrost forms an aquiclude at the base of the suprapermafrost aquifer. In other words, permafrost does not transmit significant quantities of water under ordinary hydraulic gradients. Others discuss processes that can lead to fracturing in the upper meter or so of permafrost and diffusion of contaminants in unfrozen water within permafrost at rates of centimeters per year, typically in areas in which the top of the permafrost is subject to greater seasonal temperature variations than in the North Pole area (see Biggar, 2004 and McCarthy, Walker, and Vigoren, 2004).

3.6 Soil Impacts

Evidence of soil impacts have been observed at NPR historically, and during recent investigations, including this site characterization, the laboratory drain investigation, and the sump investigation. These investigations provide some additional information regarding soil conditions at NPR; however, needs still exist in the understanding of the nature and extent of the soil impacts.

3.6.1 Historical Results

Historical analytical data (Appendix I) from the four soil borings and four monitoring wells installed in 2001 (Figure 7) indicated that ADEC soil cleanup levels (SCLs) were exceeded as follows:

- Benzene at B-1, B-2, B-4, MW-135, and MW-139;
- Toluene at MW-135;
- Ethylbenzene at B-1, B-4 and MW-135;

- Xylenes at B-1 and MW-135;
- Naphthalene at B-1; and
- GRO and DRO at B-1, B-4, and MW-135

Arsenic was also reported to exceed SCLs at all locations; however, the concentrations are consistent with natural background levels in the region.

Since the samples were collected within the range of water table fluctuations, it is unknown if the impacts were due to a release near the boring, or from impacts that had migrated in groundwater. The soil impacts were not delineated horizontally or vertically (Appendix I).

Analytical data collected in 2004 from the railcar-loading area indicate that surficial soils (<1.0 feet BGS) collected at twelve of the fifteen sampling locations contained RRO at concentrations that exceed the SCL. Deeper soil samples collected at each of these twelve locations were reported to contain RRO; however, the concentrations were below the SCL. DRO concentrations in thirteen of the fifteen samples exceeded the SCL. At eight of these locations, the deeper sample also contained DRO at a concentration exceeding the SCL. No further work was completed to determine the depth of the DRO impacts (Appendix I).

3.6.2 Site Characterization

As stated in Section 2.4.1, soil samples were selected from the well screen intervals of several well borings installed in 2010 (Figure 7) for laboratory analysis. All soil samples exhibiting evidence of impacts were collected from onsite well borings.

No soil samples collected from offsite well borings were reported to contain sulfolane (Table 14). Resulting analytical data from the onsite well borings indicated that ADEC SCLs were exceeded as follows:

- BTEX, 2-methylnaphthalene, GRO, and DRO in soil sample collected near the water table at MW-175;
- Benzene, xylenes, 2-methylnaphthalene, GRO, and DRO in sample collected from 5.0 to 6.5 feet BGS at MW-176C;
- Benzene, 2-methylnaphthalene, and DRO in sample collected near the water table MW-178C;

- Benzene in a sample collected near the water table MW-180C;
- Benzene, ethylbenzene, and 2-methylnaphthalene in a sample collected near the water table MW-186C;
- BTEX; 1,2,4-TMB; 1,3,5-TMB; n-butylbenzene; n-propylbenzene; sec-butylbenzene; naphthalene; 2-methylnaphthalene; dibenzofuran; GRO; and DRO in samples collected near the water table (7.5-11.5 feet BGS) at O-2; and
- Benzene in a sample collected from below the water table (15-16.5 feet BGS) at O-2.

At MW-175, MW-176C, MW178C, MW180C, and MW-186C, the depths of the impacted zones exceeding SCLs are unknown since no additional samples were collected, or the next analytical sample was at least 75 feet below the impacted sample. The horizontal extents of the impacted zones have not been delineated.

At O-2, the deeper sample indicated that most of the compounds exceeding SCLs were confined to the interval near the water table. The horizontal extent of the impacted zone has not been delineated.

Sulfolane was reported in soil samples collected near or below the water table at O-1 and O-2 (Table 14). LNAPL will be collected from O-2 for laboratory analysis, as described in Section 8.3. The soil investigation described in Section 8.0 will serve to determine the extent of these impacts.

3.6.3 Laboratory Drain Investigation

Soil sample analytical results from soil borings SBLAB-1 through SBLAB-5 were compared to the ADEC SCLs for migration to groundwater in the under 40-inch zone.

Soil samples collected from soil boring SBLAB-4 from 1.6 to 1.8 feet BGS and 3.8 to 4.0 feet BGS contained concentrations of DRO above the SCL of 250 milligrams per kilogram (mg/kg) with concentrations of 5,650 mg/kg (5,440 mg/kg in the duplicate sample) and 260 mg/kg, respectively. In addition, the soil sample collected from soil boring SBLAB-4 at 1.6 to 1.8 feet BGS contained a concentration of 1-methylnaphthalene above the SCL of 6.1 mg/kg with a concentration of 16.6 mg/kg (18.3 mg/kg in the duplicate sample).

Soil samples collected from soil boring SBLAB-1 from 3 to 3.2 feet BGS and 5.2 to 5.4 feet BGS contained concentrations of arsenic above the SCL of 3.9 mg/kg with concentrations of 4.92 mg/kg

and 4.13 mg/kg, respectively. However, these concentrations are below naturally-occurring background concentrations in the area of NPR.

With the exceptions noted above, concentrations of the analyzed parameters were below the respective laboratory detection limit or SCL. Soil sample analytical results are summarized in Table 6. Soil sample analytical laboratory reports are included in Appendix F.

3.6.4 Sump Investigation

With the exception of DRO, concentrations of the analyzed parameters were below their respective SCLs in the soil sample collected at the Asphalt Sump. DRO was reported to be present at a concentration (2400 mg/kg) that exceeds the SCL (Appendix H).

The reported concentrations of DRO in the soil samples collected near the floor drain and the cleanout fitting associated with the Blend Building Sump exceeded the SCL. The concentrations of methylnaphthalenes exceed their respective SCLs in the sample collected near the cleanout fitting. Sulfolane was reported in the sample collected from beneath the floor drain. The impacted areas are located beneath a floor slab and are, therefore, protected from precipitation and potential leaching (Appendix H).

The reported concentrations of DRO, benzene, and the methylnaphthalenes in the base of excavation sample from the Tank Farm Truck Kero Sump exceeded their respective SCLs. The concentrations of GRO, DRO, and BTEX reported in the excavated soil samples were reported to exceed their respective SCLs. The impacted area is located beneath an indoor floor slab and is, therefore, protected from precipitation and potential leaching (Appendix H).

The 2009-2010 Sump Investigation is further described in FHRA's December 8, 2010 report to ADEC (Appendix H). The sump investigation is being conducted pursuant to a March 16, 2011 work plan and under the direction of Brian Jackson of the ADEC Spill Prevention and Response Unit.

3.7 NAPL

NAPL evaluation is an important component of Site Characterization, as LNAPL can continue to act as a source of dissolved-phase contaminants and, as such, LNAPL is a primary target of ongoing and future corrective action. Trends in LNAPL occurrence may be used to determine if a release is ongoing, and will be a tool used to evaluate the effectiveness of cleanup actions. The following sections provide a summary of LNAPL data collected thus far during site characterization. Data collection is ongoing, and Section 8.0 – Recommendations includes specific details for additional

data gathering to further develop the LNAPL conceptual model in support of both site characterization and remediation activities.

While DNAPL is not expected to be present, data have been collected from deep monitoring wells to determine if an additional investigation regarding potential DNAPL is necessary.

3.7.1 LNAPL Occurrence

LNAPL thickness data for the fourth quarter of 2010 and first quarter of 2011 are shown on Figures 36 and 37, respectively.

LNAPL has historically been detected in wells onsite. During gauging activities conducted during the fourth quarter of 2010, LNAPL was observed in several wells located onsite (Figure 36):

- Near CU #2, at wells MW-115 (0 to 0.90 feet) and MW-138 (0.18 to 0.70 feet);
- Near containment area CA5A/CA5B, at wells R-18 (0.33 – 0.68 feet), R-32 (0.20 to 1.25 feet), R-34 (0 to 0.67 feet), S-20 (1.80 feet), S-21 (0.25 feet), and S-22 (1.90 feet);
- Near containment area CA6, at wells R-35 (0 to 6.08 feet), R-39 (0 to 1.82 feet), S-33 (1.45 feet), and S-44 (1.70 feet);
- Adjacent to containment area CA4 at R-40 (0 to 0.86 feet), S-38 (0.25 feet), S-39 (1.26 feet); and
- Near the former truck-loading rack at R-21 (0.13 to 4.82 feet), S-50 (2.20 feet), S-51 (1.55 feet), and S-52 (0.30 feet).

Recovery wells R-21 and R-35 were actively pumping at the time that the highest LNAPL thicknesses were measured. Active pumping creates a groundwater cone of depression which serves to accumulate LNAPL in the well (i.e., sumping effect).

LNAPL was observed in many of the same wells during the first quarter of 2011, (Figure 37):

- Near CU #2, at well MW-138 (0.18 to 0.35 feet);
- Near containment area CA5A/CA5B, at wells R-18 (0.30 to 1.24 feet), R-32 (0.05 to 0.45 feet), R-34 (0 to 0.30 feet), S-20 (1.20 feet), S-21 (0.39 feet), and S-22 (1.10 feet);

- Near containment area CA6, at wells R-35 (0 to 0.05 feet) and S-44 (1.20 feet);
- Adjacent to containment area CA4 at R-40 (0.02 to 0.82 feet) and S-39 (0.48 feet); and
- Near the former truck-loading rack at R-21 (0.64 to 6.56 feet), S-50 (1.69 feet) and S-51 (1.51 feet).

LNAPL was also observed at MW-176A; however, an accurate measurement of the thickness was not obtained.

The significant decrease in product thickness at R-35 from 2010 to 2011 corresponds to a collapse of the well screen and inactivation of the pump in November 2010. Recovery well R-21 was again actively pumping at the time that the highest LNAPL thickness was measured in 2011, and this thickness may have been exaggerated due to sumping effects in the wells.

3.7.2 LNAPL Thickness Trends and Responses to Water Table Fluctuations

Historical data from onsite wells (Appendix N) were used to prepare hydrographs that include LNAPL thickness data in order demonstrate responses in LNAPL thicknesses to water table fluctuations (Figures 38, 39, and 40). Additional graphs prepared using data from the observation wells, which were measured less frequently, are provided in Appendix N. As expected, at many locations measured LNAPL thickness generally increases as the water table elevation decreases. Therefore, LNAPL thicknesses are generally highest during the seasonal low water table periods of winter and early spring, and lower during the summer when the water table is higher. Also, LNAPL thicknesses increase in recovery wells when they are actively pumping, which lowers the water table, and sumping effects can further exaggerate LNAPL thicknesses in active recovery wells such as R-21 (Figure 40).

Observation wells exhibiting increasing LNAPL thicknesses with decreasing water table elevations, and vice versa, include S-20, S-22, S-33, S-39, S-44, and S-50 (Appendix N). These monitoring wells are likely to be in locations where LNAPL becomes trapped in the aquifer matrix when submerged by the rising water table (typically referred to as a ‘smear’ zone). The elevation of this trapped NAPL is likely between 485.5 and 486 feet, based on the observed responses.

Observation wells containing LNAPL whose thickness do not appear to respond to changes in water table elevation include S-21, S-32, S-38, and S-51 (Appendix N).

3.7.3 Bail-down Test Results

LNAPL bail-down testing was performed at four wells, as discussed in Section 2.5.2, to begin gauging LNAPL recoverability. The following table presents a summary of measurements recorded during the bail-down tests:

Well (diameter)	In Well LNAPL Thickness	LNAPL Volume Removed		Final LNAPL Thickness	Test Duration
		Calculated	Actual		
S-21 (2 inches)	0.39 feet	0.4 gallons	0.4 gallons	0.35 feet	35 minutes
S-44 (4 inches)	1.20 feet	1.8 gallons	0.8 gallons	0.03 feet	90 minutes
S-51 (2 inches)	1.51 feet	1.5 gallons	1.5 gallons	1.20 feet	60 minutes
MW-138 (2 inches)	0.18 feet	0.2 gallons	0.6 gallons	0.17 feet	15 minutes

The LNAPL samples from all four wells were described as having low viscosities. Samples from wells S-21 and S-44 were clear. The sample from well S-51 was dark brown to black and the MW-138 sample had a medium brown color and low viscosity.

The final LNAPL thicknesses at S-21, S-51, and MW-138 are approximately 90%, 79%, and 94% of their initial apparent LNAPL thicknesses, respectively. The final thickness at S-44, the only four-inch diameter well tested, was 2.5% of the initial thickness.

The recoverability of LNAPL during the bail-down testing was generally good, with the exception of S-44. Results of this bail-down testing, as well as future bail-down testing, will be used to compute LNAPL transmissivity for comparison to ITRC benchmark values to evaluate LNAPL recoverability.

3.7.4 LNAPL Conceptual Model

As described in the SCWP, the LNAPL conceptual model (LCM) is a body of site-specific knowledge concerning the lateral and vertical distribution, chemical composition, and relative mobility of LNAPL, as well as the distribution of aqueous-phase LNAPL constituents. The LCM serves as the basis for several important inputs to the remediation process:

- Estimate of LNAPL recoverability;
- Evaluation of interim remedial system performance;
- Selection of long-term remedial alternatives;
- Development of metrics for assessing performance of the long-term remedial technology; and

- Establishment of criteria for closure of the site.

The data collected to date, and described in the previous sections, constitute a partial framework for development of the LNAPL conceptual model. The model will be further developed as the remainder of the data outlined in the SCWP are collected, and updated as additional data are collected in the future. Additional information regarding scope and schedule are presented in Section 8.3. The following sections describe the framework for the various LCM components based on data collected to date, and outline how future data will be incorporated to fully develop the LCM.

3.7.4.1 Distribution of Mobile LNAPL

Data collected to date regarding vertical and lateral extent of LNAPL consists of product thickness measurements described in Section 3.7.1, which includes three of the four additional observation wells (well O-1 was frozen at the time of measurement) proposed in the SCWP. The absence of product from wells O-3 and O-4 suggest that east-west extent of LNAPL at the north end of the site may be defined, as shown on Figures 36 and 37. Due to the presence of 0.55 feet LNAPL in well O-2, product recovery was initiated. A product recovery system will be installed in the well to provide continuous removal of product and to prevent potential migration of product in the area of this well. Measurements at O-1 will be required to define the extents of mobile LNAPL between CU #2 and containment area CA5A/CA5B.

3.7.4.2 Preliminary Recoverability of LNAPL

Bail down testing conducted at S-21, S-44, S-51, and MW-138 provided a preliminary indication of the recoverability of LNAPL in the vicinity of the remediation system, and upgradient of the system. LNAPL recoverability in the vicinity of well S-44 was notably lower than in the other three wells although this test may not have been representative due to the amount of water that was removed from the well during the bail-down test. Additional bail-down testing will be repeated at these locations, and conducted at additional locations to further characterize mobility of NAPL at the site.

3.7.4.3 Distribution and Composition of Smear Zone LNAPL

Smear zone LNAPL sampling results are in Table 15. In the vicinity of well O-1, sulfolane and benzene were detected in the sediment samples taken from below 12 feet BGS (near the water table). The remaining LNAPL constituents were not detected in the vicinity of well O-1. Thus, smear zone LNAPL is not apparent in the vicinity of well O-1.

In the vicinity of well O-2, sulfolane and other NAPL constituents were detected above the water table (7.5 to 9 feet BGS). NAPL constituents, but not sulfolane, were detected below the water table

at depths greater than 10 feet BGS. Thus, smear zone NAPL is apparent in the vicinity of well O-2, primarily from a depth of 7.5 feet BGS to 11.5 feet BGS. The composition of NAPL in the smear zone at O-2 was similar to that of NAPL collected at nearby S-33 (see Section 3.7.4.4) in that the most abundant constituent was meta/para-xylene. In the vicinity of wells O-3 and O-4, no NAPL constituents were detected above or below the water table, suggesting that smear zone NAPL is not present in the vicinity of O-3 or O-4.

3.7.4.4 Composition of Mobile LNAPL

Results for composition sampling of mobile LNAPL are summarized in Table 16. Also shown in Table 16 are the concentrations of LNAPL constituents expressed as mole fractions. Equilibrium aqueous concentrations corresponding to the calculated NAPL mole fractions were also computed and are listed in Table 16. It can be seen from Table 16 that the NAPL with greatest potential to contribute benzene, ortho-xylene, and 1,2,4-trimethylbenzene to groundwater is in the vicinity of MW-138. The NAPL with greatest potential to contribute toluene to groundwater is in the vicinity of S-39. The NAPL with greatest potential to contribute ethylbenzene and para/meta xylene to groundwater is in the vicinity of S-33. The NAPL sample from MW-138 contained 573 µg/kg sulfolane, whereas sulfolane was below reporting limits in the other NAPL samples. As additional groundwater COPC data are collected in the future, they will be compared to the equilibrium values for NAPL in the vicinity to evaluate the stability of the plume relative to equilibrium with groundwater.

Physical measurements conducted on mobile LNAPL are in Table 17. The viscosity of the LNAPL varied significantly, with the most viscous LNAPL occurring in the vicinity of MW-115 and R-33 near CUs #1 and #2 (Figure 37). It should be noted that viscosity measurements were conducted at 15°C, while groundwater temperatures have a seasonal high of 5°C. Thus, the in-situ viscosity is likely lower than the measured value. Future sampling will include viscosity analyses at groundwater temperatures.

3.7.5 Adequacy of LNAPL Monitoring Network

An additional observation well is recommended north of O-2 to better confirm product recovery from this well is effective.

If LNAPL is observed in O-1 in the future, then existing nearby monitoring wells MW-176A, MW-178A, and MW-179A will provide the data necessary to define lateral LNAPL extents.

Additional smear zone LNAPL composition data will be collected from the vicinity of MW-138, S-44, S-22, and S-51 to better characterize the thickness and composition of smear zone NAPL in these locations, as they exhibited an inverse relationship between LNAPL thickness and water table elevations, evidence of possible submerged LNAPL.

Specific details regarding scope and schedule are present in Section 8.0 Recommendations.

3.7.6 DNAPL Assessment

Deep monitoring wells downgradient of Tank 194 were analyzed for sulfolane as part of the DNAPL assessment. Results for well nests MW-174, MW-176, MW-178, and MW-179 (Table 18) show the samples collected from the deepest well at each location had the lowest concentration at that nest (all four deep wells were nondetect for sulfolane). If DNAPL had been present, sulfolane would likely have been detected in the deep well samples, with potentially higher concentrations than the shallow wells. DNAPL would not be expected to be present as DNAPL because of its miscibility with water.

3.8 Groundwater Impacts

Groundwater impacts have been, and continue to be, characterized through the analysis of groundwater samples collected from onsite and offsite monitoring wells. This section includes results of analyses completed on onsite well samples (analyzed for COPCs BTEX, 1,2,4-TMB, and/or sulfolane) and offsite well samples (sulfolane) since initiation of site characterization activities, including the first quarter of 2011. BTEX; 1,2,4-TMB; and sulfolane data are presented on Table 18.

3.8.1 Benzene

Benzene data from sampling events completed during the fourth quarter of 2010 and the first quarter of 2011 were plotted on Figures 40 and 41, respectively, to show the extent of the dissolved-phase benzene plume. For locations at which multiple sampling events were completed during the quarter, the results were averaged. Due to the range of concentrations measured across the site, a logarithmic contour interval is used on the maps. The 100- $\mu\text{g/L}$ isopleth is drawn around those wells in which LNAPL was present during each quarter. The data indicate that the benzene plume is present beneath the tanks farms and CUs #1 and #2, extending north under the current truck-loading rack and west beneath Lagoons B and C. The extent of the benzene plume is shown as an isopleth of 5 $\mu\text{g/L}$, which equals the ADEC groundwater cleanup level for benzene.

During the fourth quarter of 2010, the extent of the plume is defined by results less than 5 $\mu\text{g/L}$ in wells MW-109, MW-111, MW-113, and MW-143 to the west; wells MW-126, MW-127, MW-131,

MW-140, MW-142, MW-144A, and MW-145 to the north; wells MW-124, MW-132 and MW-134 to the east, and MW-105 and MW-105A to the south.

During the first quarter of 2011, the extent of the plume is defined by results less than 5 µg/L in wells MW-109, MW-111, and MW-113 to the west; wells MW-126, MW-140, MW-144A, and MW-145 to the north; and wells MW-124, MW-132 and MW-133 to the east.

Figures 40 and 41 show that the benzene plume is confined to the developed portion of the NPR property, and does not extend to the property boundary or beyond. The 2010 and 2011 5-µg/L footprints appear to be similar to the footprint in 2002 as shown on Figure 17 of the SCWP.

3.8.2 Toluene

Fourth quarter 2010 and first quarter 2011 toluene concentration data were plotted on Figures 43 and 44, respectively. For locations at which multiple sampling events were completed during the quarter, the results were averaged. During the fourth quarter of 2010, toluene concentrations in samples from only two wells, MW-135 and MW-136 were reported to exceed ADEC groundwater ADEC cleanup level of 1,000 µg/L; none of the 2011 results exceed this criteria. Due to the small number of wells with resulting concentrations above the criteria, the data have not been contoured. All wells with positive toluene results are located within the footprint of the benzene plume, and several wells at which benzene was reported did not contain toluene above the PQL.

3.8.3 Ethylbenzene

Ethylbenzene data from the fourth quarter of 2010 and the first quarter of 2011 were plotted on Figures 45 and 46, respectively. For locations at which multiple sampling events were completed during the quarter, the results were averaged. None of the fourth quarter 2010 or first quarter 2011 results were reported to exceed ADEC groundwater screening criteria of 700 µg/L; therefore, the data were not contoured. The data indicate that the ethylbenzene plume occurs within the footprint of the benzene plume.

3.8.4 Xylenes

Total xylenes concentrations from the fourth quarter of 2010 and the first quarter of 2011 were plotted on Figures 47 and 48, respectively. For locations at which multiple sampling events were completed during the quarter, the results were averaged. None of the fourth quarter 2010 or first quarter 2011 results were reported to exceed ADEC groundwater screening criteria of 10,000 µg/L; therefore, the data were not contoured. The data indicate that the xylenes plume occurs within the footprint of the benzene plume.

3.8.5 1,2,4-Trimethylbenzene

No samples were analyzed for 1,2,4-TMB in 2010. Data from the first quarter of 2011 were plotted on Figure 49. None of the concentrations were reported to exceed ADEC groundwater screening criteria of 1,800 µg/L. Due to a lack of resulting concentrations above the PQL, the data have not been contoured. All wells with positive 1,2,4-TMB results are located within the footprint of the benzene plume.

3.8.6 BTEX & 1,2,4-TMB Data Evaluation

As stated in Section 2.6.4, a statistical trend analysis of groundwater analytical data is being used to evaluate plume migration and stability, to evaluate cleanup action effectiveness, and to identify relationships between dissolved-phase concentrations and groundwater elevations and flow directions. Results of the trend analysis are summarized in Table 19.

Since 1,2,4-TMB was only recently added to the groundwater parameter list, trend data are not available for this constituent. Also, eight wells were added to the network during site characterization; therefore, insufficient data are available to evaluate their results.

3.8.6.1 Nondetects, Decreasing, or Stable Trends

As shown in Table 19, nondetects, decreasing trends, probably decreasing, or stable trends were indicated at most wells in the BTEX network. This includes wells within the plume, such as MW-115, MW-116, MW-124, and MW-137, and also wells located near the edge of the plume, such as MW-109, MW-111, MW-113, MW-126, MW-127, MW-132, MW-134, MW-140, MW-142, MW-145 (Figure 42).

3.8.6.2 Increasing Trends

The statistical analysis indicated increasing trends for one or more BTEX parameters at wells MW-110, MW-125, MW-135, MW-136, MW-139, and MW-143.

At MW-110, an increasing trend was indicated for xylenes, with no trends indicated for benzene, toluene, and ethylbenzene. MW-110 is located between Lagoons B and C (Figure 42). A visual inspection of the MW-110 concentration graph (Appendix O) indicated that, in general, BTEX concentrations have decreased since 1999. Since 2008, concentrations have followed a pattern of increasing in the second and third quarters, followed by a period of decreasing in the fourth and first quarters, a trend that may correspond with water table fluctuations. Sufficient water elevation data have not been gathered to correlate concentrations with water table fluctuations at this location. Since 2008, each successive annual peak has decreased in magnitude, indicating a downward trend in

concentrations. Since the MAROS software does not account for seasonal variations, its analysis of the MW-110 data may be inaccurate.

Results of the statistical analysis indicated increasing xylenes concentrations at MW-125, with decreasing or probably decreasing benzene, toluene, and ethylbenzene concentrations. MW-125 is located north of containment area CA6 (Figure 42). The MW-125 concentration graph shows a potentially increasing trend in xylenes from 2006 through 2009, with decreased concentrations in 2010 (Appendix O).

At MW-135 and MW-136, increasing trends were indicated for toluene, ethylbenzene, and xylenes. For benzene, no trend was indicated at MW-135 and a stable trend was indicated at MW-136. These wells are located just north of the tank farms near the northern edge of the plume (Figure 42). A visual inspection of the concentration graphs (Appendix O) indicated that BTEX concentrations peaked in the third quarter of 2008 at both wells, and have decreased with minor, likely seasonal, fluctuations since. Insufficient water elevation data are available to correlate with the concentration data at this location. Therefore, the MAROS characterization of these trends as increasing may be inaccurate.

At MW-139, an increasing trend was indicated for ethylbenzene, while decreasing trends were indicated for benzene and xylenes, and no trend was indicated for toluene. MW-139 is located west of the truck-loading area (Figure 42). Xylenes concentrations have fluctuated since 2002, but the concentration graph (Appendix O) shows that the xylenes concentration peaks have been decreasing since 2005. Correlation of water table fluctuations with constituent concentrations is not yet possible due to a lack of groundwater elevation data. Since the MAROS software does not account for seasonal variations, its analysis of the MW-139 data may be inaccurate.

The statistical analysis indicated an increasing trend for benzene at MW-143. MW-143 is currently located beyond the northwestern tip of the plume (Figure 42). A small benzene peak of 2.21 µg/L was noted during first and second quarters of 2009; however, benzene has not been detected in the well since October 2009 (Appendix O). Insufficient water elevation data are available to correlate with concentration data at this location.

In summary, MAROS-indicated increasing trends at wells MW-110, MW-135, MW-136, MW-139, and MW-143 are likely due to fluctuating concentrations that are more likely due to seasonal variations in water table elevation, as visual inspections of concentration graphs for these wells

indicate decreasing or stable trends. At MW-125, xylenes concentrations appeared to be increasing until 2010.

3.8.6.3 No Trend

At several wells including MW-101, MW-101A, MW-102, MW-105, MW-105A, MW-129, and MW-144A, no trends were indicated for at least three parameters. As their concentration graphs show (Appendix O), these wells typically are nondetect for BTEX, with only occasional nonconsecutive detections; therefore, concentrations do not appear to be increasing at these locations.

3.8.7 Sulfolane

Maps have been prepared to show the recent sulfolane concentrations measured in groundwater samples collected from wells screened at various depths in the aquifer during the fourth quarter of 2010 and the first quarter of 2011 (Table 18). All of the wells are located in the suprapermafrost portion of the aquifer. Due to the range of concentrations measured across the plume, a logarithmic contour interval is used on the maps.

Many of the wells were sampled multiple times during the fourth quarter; therefore, fourth quarter results values were averaged and plotted on the maps.

Since dissolved-phase sulfolane has been detected at various depths in the aquifer, the following discussion breaks up the data into depth intervals as follows: water table, 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table. Depths below ground surface are avoided since the ground surface is not flat. Elevations with respect to mean sea level are also avoided due to the large nature of the site, and the fact that the water table elevation decreases several feet from southeast to northwest.

3.8.7.1 Water Table

Figures 50 and 51 indicate that the sulfolane plume is present at the water table under CUs #1 and #2 and the tank farms, extending north-northwesterly (downgradient) offsite from NPR.

The maximum potential extent of the plume at the water table during the fourth quarter of 2010, shown as the 25 µg/L isopleth, is defined by results less than 25 µg/L at wells MW-109, MW-116, MW-124, MW-132, MW-141, MW-144A, MW-145, MW-146A, MW-147A, MW-149A, MW-155A, MW-159, MW-165A, MW-166A, MW-167A, MW-168, MW-169A, MW-170A, MW-171A, MW-172A, MW-173A, MW-180A, MW-181A, MW-182, MW-185A, and MW-187. The highest concentrations were reported at onsite wells MW-110 (1390 µg/L) near Lagoon B and MW-176A

(2050 µg/L) downgradient of CU #2 (Figure 50). The highest offsite concentrations were reported at wells MW-151A (106 µg/L), MW-156A (121 µg/L), and MW-158A (118 µg/L). All three wells are located in an area bounded by North Pole High School Boulevard, Homestead Road, Perimeter Road, and Holiday Drive (Figure 50).

Results from the first quarter of 2011 show a maximum potential plume extent as shown on Figure 51. The plume is similar to previous interpretations, with minor changes likely due to fluctuating concentrations. Results less than 25 µg/L were reported at MW-106, MW-109, MW-132, MW-141, MW-144A, MW-145, MW-149A, MW-155A, MW-165A, MW-167A, MW-168, MW-169A, MW-170A, MW-171A, MW-172A, MW-173A, MW-180A, MW-181A, MW-185A, and MW-187. The highest concentrations were reported at onsite well MW-130 (930 µg/L) in the tank farm, while the concentration decreased from 1390 µg/L to 233 µg/L at MW-110 (Figure 51).

On March 8, 2011, Reiss Remediation submitted to ADEC a proposal for fourteen new delineation wells. The wells were proposed since initial analytical data from wells installed during the fall of 2010 and cross-sectional information helped to identify areas (data needs) where more delineation may be prudent. ADEC approved the proposal on May 23, 2011 and installation will be completed during the 2011 field season. Further information regarding these wells is provided in Section 8.5.

3.8.7.2 10 to 55 Feet below the Water Table

Figures 52 and 53 indicate that sulfolane is present at depths of 10 to 55 feet below the water table. Onsite, the plume is present below the tank farms, but apparently not below CU #1 or CU #2. The plume extends north-northwesterly (downgradient) offsite from NPR, in a manner similar to the water table plume.

The maximum potential extent of the plume at a depth of 10 to 55 feet below the water table during the fourth quarter of 2010 (Figure 52), shown as the 25 µg/L isopleth, is defined by results less than 25 µg/L at wells MW-101, MW-102, MW-118, MW-146B, MW-147B, MW-153B, MW-155B, MW-165B, MW-166B, MW-167B, MW-169B, MW-170D, MW-171B, MW-176B, MW-179B, MW-180B, MW-181B, MW-184, and MW-185B. The highest reported concentrations were at MW-148B (316 µg/L) near the property boundary and MW-178B (237 µg/L) downgradient of CU #2. The highest offsite concentrations were reported at wells MW-158B (136 µg/L) north of North Pole High School, MW-161B (243 µg/L) west of Bradley Sky Ranch, and MW-164 B (113 µg/L), located north of Richardson Highway along Peridot Street (Figure 52).

Data from the first quarter of 2011 show a maximum potential plume extent, as shown on Figure 53. Results less than 25 µg/L were reported at MW-101, MW-104, MW-129, MW-147B, MW-153B, MW-155B, MW-165B, MW-167B, MW-169B, MW-170D, and MW-171B. The highest concentration was reported at MW-148B (501 µg/L) near the property boundary. The highest offsite concentrations were reported at wells MW-158B (102 µg/L) north of North Pole High School, MW-161B (269 µg/L) west of Bradley Sky Ranch, and MW-164 B (104 µg/L), located north of Richardson Highway along Peridot Street (Figure 53).

As noted above in Section 3.8.7.1, fourteen new delineation wells have been proposed to ADEC. Eight of the wells will be installed to a depth of approximately 50 feet below grade, and will serve to further delineate the plume at this depth. Further information regarding these wells is provided in Section 8.5.

3.8.7.3 55 to 90 Feet below the Water Table

As shown on Figures 54 and 55, sulfolane has been detected in samples collected from wells screened 55 to 90 feet below the water table. The figures show that a limited number of monitoring wells have been installed at this depth due to presence of permafrost in the area. The upgradient end of the plume appears to be located near the former truck-loading rack, and the plume extends north-northwesterly (downgradient) offsite from NPR. The permafrost may be limiting lateral migration of the plume at this depth (Figures 54 and 55).

Results from the fourth quarter of 2010 show a maximum potential plume extent as shown on Figure 54. Results less than 25 µg/L were reported at MW-144B, MW-170B, MW-174B, MW-175, MW-176C, MW-177, MW-178C, MW-179C, and MW-180C. The highest concentration was reported at offsite well MW-160B (115 µg/L) near Old Richardson Highway and Perimeter Road (Figure 54).

The maximum potential extent of the plume during the first quarter of 2011 (Figure 55), shown as the 25 µg/L isopleth, is defined by results less than 25 µg/L at wells MW-144B, MW-170B, MW-174B, and MW-180C.

Due to the presence of permafrost west and north of the plume, no additional wells have been proposed at this depth.

3.8.7.4 90 to 160 Feet below the Water Table

Figures 56 and 57 shows fourth quarter 2010 and first quarter 2011 data, respectively, from the three monitoring wells installed between 90 and 160 feet below the water table. Sulfolane has not been

detected in samples collected from these wells. Based on these results and the presence of permafrost at shallower depths north and west of these, no additional wells have been proposed at this depth.

3.8.7.5 Private Well Results

As stated in Section 2.6.2.6, groundwater samples have been collected from 404 private wells located within the search areas downgradient of NPR and analyzed for sulfolane. Results ranged from nondetect (<limit of quantitation [LOQ]) to 443 µg/L. Results are graphically presented on Figure 58 and are summarized as follows:

- Less than the LOQ: 205 wells;
- Greater than the LOQ and less than 25 µg/L: 67 wells;
- Greater than 25 µg/L: 132 wells; and

The map shows that sulfolane occurrence in private wells generally corresponds with sulfolane occurrence in monitoring wells.

3.8.8 Sulfolane Data Evaluation

As stated in Section 2.6.4, a statistical trend analysis of sulfolane data from monitoring wells is being used to evaluate plume migration and stability, to evaluate cleanup action effectiveness, and to identify relationships between dissolved-phase concentrations and groundwater elevations and flow directions. Private well results are not evaluated since multiple samples have not been collected from most private wells.

Results from the MAROS statistical analysis of 116 wells are summarized in Table 20. Due to the fact that many of the wells have been installed recently, 44 wells have generated insufficient data to complete the trend analysis.

3.8.8.1 Nondetects, Decreasing, or Stable Trends

As shown in the table, 25 locations have always been nondetect for sulfolane. Results indicated that concentrations at 23 wells are decreasing or probably decreasing, while seven are stable (Table 20). These include most of the water table wells and most of the wells screened 10 to 55 feet below the water table located within the plume, from NPR northwestward through the Ford Subdivision to Homestead Drive/Peridot Street (Figures 51 and 53). Also included are deeper onsite wells MW-154A and MW-154B.

3.8.8.2 Increasing Trend

The statistical analysis indicated an increasing or probably increasing trend for sulfolane at only two wells, MW-142 and MW-161A (Table 20). Concentration graphs for these two wells are provided in Appendix O.

Well MW-142 is a water table well located onsite at NPR, just northwest of the truck-loading area (Figure 51). Visual inspection of the MW-142 concentration graph indicates that the sulfolane concentrations may have been increasing from September 2007 through March 2009, but since that time they have been consistently fluctuating between 370 µg/L and 690 µg/L. Insufficient water elevation data are available to correlate the concentration data with water table fluctuations at this location. In addition, nearby water table wells located upgradient (MW-139), downgradient (MW-143), and sidegradient (MW-101A and MW-131) to MW-142 are all characterized as having decreasing trends. Therefore, the MAROS-indicated trend at MW-142 may be inaccurate.

MW-161A is a water table well located approximately 9,000 feet downgradient of NPR, west of the Bradley Sky Ranch (Figure 51). The statistical analysis indicates that no other wells between MW-161 and the NPR property boundary have increasing trends. Trends have yet to be established for wells located sidegradient (MW-187) or downgradient (MW-183) of MW-161A (Table 20). Correlation of water table fluctuations with constituent concentrations is not yet possible due to a lack of groundwater elevation data; groundwater monitoring at this well will continue to allow for further evaluation of the concentration trend.

3.8.8.3 No Trend

No trend was indicated at 16 wells. For several of these wells, this is likely due to fluctuating concentrations near the plume boundaries, such as those seen at MW-149A, MW-149B, MW-153B, MW-159, MW-160B, MW-166A, MW-166B, and MW-169A (Appendix O and Figure 51). Sufficient groundwater elevation data have not been collected to correlate the concentration fluctuations to water table fluctuations.

Other wells which have no trend have occasional sulfolane detections in the midst of long periods of nondetects such as MW-106, MW-109, and MW-141. All three wells are located onsite near the western edge of the plume (Figure 51).

No trend was also indicated for two onsite wells, MW-127 and MW-134. Sulfolane concentration graphs for the two wells (Appendix O) show that sulfolane concentrations have apparently been decreasing since April 2008 and September 2007, respectively. Both wells are located onsite, with

MW-127 located within the plume and MW-134 located near the eastern edge of the plume (Figure 51).

3.9 MNA Evaluation Results

This section presents results thus far from the ongoing MNA evaluation and also a geochemistry evaluation. As previously stated, the MNA data collected will be used as an element of a future feasibility study to evaluate remedial alternatives for offsite sulfolane impacts. Also, as previously mentioned, information collected as part of ongoing onsite remediation pilot testing, as well as bench and pilot testing associated with the POE treatment systems, will be leveraged to enhance FHR's understanding of MNA, as well as other potential remedial alternatives.

3.9.1 Evaluation of Microbially-Mediated Processes

The results of MNA sampling are summarized in Table 21, and select results are shown on Figure 59. As previously described, data collected to date were limited to a single partial round of sampling. In accordance with the SCWP, the MNA analysis will be updated as additional data become available.

While additional data will be required to perform more rigorous statistical hypothesis testing regarding temporal and spatial trends (e.g., Mann-Kendall analysis), some preliminary insight into potential MNA trends can be gained via principal component analysis (PCA), using the data collected thus far. PCA is a multivariate statistical method that compares multiple parameters simultaneously based on the way in which they contribute to the overall variability in a data set. While PCA does not test statistical significance of any observed correlations, it can provide a broad overview of multiple contemporaneous parameters and reveal potential correlations whose statistical significance can be tested via other methods.

Two groups of wells were used for PCA analysis:

- MW-142, MW-148A, MW-151A, MW-156A, MW-161A, and MW-165A; and
- MW-170A, MW-157, MW-163A, MW-164A, and MW-167A.

Two PCA plots (Figures 60 and 61) were generated using the data for each set of wells (Table 21), with the exception of nitrate, nitrite, carbonate alkalinity, and hydroxide alkalinity, as these parameters did not vary, thus they did not contribute to variability of the dataset. The PCA plot is a graphical representation of the way in which each parameter (shown as a line emanating from the origin) contributes to the overall variability of the dataset. The axes of the figure are principal

components of the dataset variability, and were selected such that the maximum percentage of overall data variability could be viewed on a two-dimensional plot.

Parameters whose variability is well-captured by the plot appear as long lines, while those whose variability is not well-captured by the plot appear as short lines. Parameters whose lines are oriented in the same direction correlate positively with one another, while those oriented in opposite directions correlate negatively. Parameters whose lines are orthogonal to one another do not correlate to one another.

It can be seen from Figure 60 that sulfolane concentration is negatively correlated with dissolved oxygen concentration – a trend which would be consistent with aerobic sulfolane degradation. Additionally, there is a positive correlation between sulfolane concentration and pH – a trend which might be indicative of biological sulfolane oxidation, which is known to be an acid-producing process. Sulfate, the aerobic degradation product of sulfolane, does not correlate with sulfolane concentration. However, it is important to note that background sulfate concentrations in the aquifer are large relative to the amount of sulfate that would be produced via sulfolane degradation, thus changes in sulfate concentration due to sulfolane degradation may be difficult to detect.

It can be seen from Figure 61 that sulfolane concentration correlates positively with pH, which might suggest biological oxidation of sulfolane, as observed in the previous analysis. However, unlike the previous analysis, dissolved oxygen does not correlate negatively with sulfolane concentration. The observed negative correlation between dissolved oxygen and reduced iron and manganese suggests that iron/manganese redox reactions may influence the dissolved oxygen concentrations in these wells.

As ongoing MNA data are collected, they will be evaluated for trends in the MNA parameters along the flow path, with depth and with time. Sampling is planned to be conducted quarterly, but the frequency may be adjusted. When sufficient data have been collected, the Mann-Kendall trend test will be applied to the data to discern increasing or decreasing trends in the data with distance and time (subject to any constraints of the method relative to seasonal variability).

3.9.2 Evaluation of Sulfolane Adsorption – Isotherm Testing

The objective for the isotherm testing outlined in the SCWP was to evaluate the possible amount of adsorbed sulfolane within the plume that may desorb during remediation/natural attenuation and affect the observed trends in sulfolane concentration by establishing site-specific distribution coefficients. As described in Section 2.6.3.2, prior to the isotherm test, the aquifer sediment was

characterized by quantifying sulfolane concentration, total organic carbon content, and bulk density. The isotherm test was then conducted by contacting sulfolane-spiked groundwater with different amounts of aquifer sediment, and measuring the resulting aqueous sulfolane concentration after one, two, and three days of equilibration time (see Section 2.6.3.2 for details).

Characterization results for the aquifer sediment used in the test are in Table 22. It can be seen from the results that the aquifer sediment had low organic content. The results of the isotherm test are in Table 23, along with the amounts of water and sediment used in each replicate.

For the purposes of data evaluation, distribution coefficients (K_{obs}) and organic carbon partition coefficients (K_{oc}) were computed and are also listed in Table 23. The methodology for computing the distribution coefficients was as follows:

- Calculation of sulfolane mass decrease in aqueous solution (assumed equal to mass increase adsorbed to the sediment) by multiplying the decrease in sulfolane concentration by the volume of water in the jar. The highest measured sulfolane concentration (535 ppb) was assumed to be the initial aqueous sulfolane concentration for the purposes of this calculation.
- Calculation of adsorbed concentration of sulfolane on sediment (micrograms per kilogram [$\mu\text{g/kg}$]) by dividing adsorbed sulfolane mass by the mass of sediment in the jar.
- Calculation of K_{obs} by dividing the calculated adsorbed concentration ($\mu\text{g /kg}$) by the measured concentration in aqueous solution.
- Calculation of K_{oc} by dividing K_{obs} by the average TOC concentration measured in the sediment. The reporting limit was assumed for the concentration of the nondetect TOC result for the purposes of this calculation.

The resulting K_{obs} values ranged from 0 to 4×10^{-4} liters per kilogram (L/kg). The resulting K_{oc} values ranged from 0 to 13.3 L/kg. While K_{obs} values are site-specific, K_{oc} values can be compared to published data. Table 24 summarizes published K_{oc} values for sulfolane and other hydrocarbons. It can be seen from the table that the measured K_{oc} values are much lower than published values for BTEX compounds, as would be expected based on the low octanol/water partition coefficient for sulfolane. For most of the measurements, the observed K_{oc} values were similar to the value published by Shell Chemicals Europe Limited (Shell) in 1994. With the exception of the two

samples described below, K_{oc} values ranged from 0 to 2.27 L/kg. The value published by Shell is 1.1 L/kg (Shell, 1994).

For two of the samples, however (those containing 500 grams [g] and 250 g of aquifer sediment at the three-day equilibration time), the observed K_{oc} values were much higher than the published value. While the reason for this phenomenon is currently unknown, the isotherm replicates were not poisoned or otherwise sterilized to inhibit microbial activity. Therefore, biological degradation cannot be ruled out as a possible explanation for the higher-than-expected sulfolane removal observed in these isotherm replicates.

The conclusion of this work is that the degree of sulfolane adsorption to aquifer sediment is anticipated to be similar to what has been published in the literature for other sites. As ongoing data collection and evaluation of monitored natural attenuation proceeds, the distribution coefficients estimated from this work will be used to estimate the mass of sulfolane adsorbed to sediment, and account for that mass when assessing MNA progress.

3.10 Geochemistry Evaluation

As described in Section 2.3.4, the objective of the geochemistry evaluation was to test the hypothesis that sulfolane impacts observed in subpermafrost private wells may be due to suprapermafrost groundwater infiltrating to the subpermafrost aquifer via well penetrations through the permafrost. Data collected for geochemical characterization of groundwater from the supra- and subpermafrost zones is in Table 25. For geochemical comparison, the samples were divided into three areas:

- Area 1 – Vicinity of the subpermafrost sulfolane-impacted well A1-1 (average sulfolane concentration: 108 $\mu\text{g/L}$).
- Area 2 – Vicinity of the subpermafrost sulfolane-impacted well A2-1 (average sulfolane concentration: 77.4 ppb $\mu\text{g/L}$).
- Area 3 – Vicinity of the subpermafrost sulfolane-impacted well A3-3 (average sulfolane concentration: 19.0 $\mu\text{g/L}$).

Stiff diagrams were created for the samples to allow comparison of the overall groundwater composition for different wells in each area. Stiff diagrams are a graphical representation of the ionic composition of a water sample. Anions are plotted to the left of the diagram, and cations are plotted to the right. The shape of the stiff diagram provides a rapid visual indication of the relative

proportions of ions in the water. Waters from the same source have similar relative proportions of ions and, therefore, the stiff diagrams have similar shapes.

In Area 1, the groundwater composition of the A1-1 well was compared to suprapermafrost samples from upgradient wells MW-162A and MW-162B. It can be seen from the stiff diagrams (Figure 62) that the subpermafrost water from the A1-1 well is characterized by a higher ratio of calcium to magnesium, as well as more copper than the suprapermafrost wells.

In Area 2, the groundwater composition of the A2-1 well was compared to unimpacted subpermafrost groundwater from wells A2-4 and A2-5, as well as suprapermafrost groundwater from MW-163A, MW-163B, MW-171A, and MW-171B. It can be seen from the stiff diagrams (Figures 63 and 64) that the compositions of all three subpermafrost wells are similar to one another. In contrast, the compositions of the subpermafrost wells differ from the suprapermafrost wells in that the ratio of calcium to magnesium is higher, and that there is more copper and zinc.

In Area 3, the groundwater composition of the A3-3 well was compared to unimpacted subpermafrost groundwater from the A3-2 well, as well as suprapermafrost groundwater from MW-164A and MW-164B upgradient. It can be seen from the stiff diagrams (Figures 65 and 66) that the compositions of the two subpermafrost samples were similar to one another. The compositions of the subpermafrost wells differ from the suprapermafrost wells in that the ratio of calcium to magnesium is higher, and that there is more copper and zinc.

While some geochemical differences can be observed between sub and suprapermafrost waters, these differences are subtle. The subtlety of these differences, along with the small number of samples, limits the conclusions that can be drawn from the geochemical analysis. While the hypothesis tested by this work cannot be accepted based on these results, it cannot currently be rejected in favor of another, better supported hypothesis. Additional work will be completed with the aim to provide a more conclusive explanation for the presence of sulfolane in the subpermafrost wells.

3.11 Gravel Pit and Surface Water Quality

As discussed in Section 2.7, samples of water were collected from the North Gravel Pit, South Gravel Pit and Badger Slough (Figure 13) for laboratory analysis. The laboratory reported that sulfolane was not detected above its LOQ of 10.0 µg/L in either of the gravel pit samples (Table 26). The laboratory reported that sulfolane was not detected above its LOQ of 10.2 µg/L in the surface water sample collected from Badger Slough (Table 26).

3.12 Updated Conceptual Site Model

As proposed in the SCWP, the CSM for NPR has been updated. A preliminary CSM was prepared and submitted to ADEC with SCWP. Since submittal of the SCWP, a substantial amount of data collection has been conducted for the site. The purpose of this section is to present a CSM that has been updated to reflect the enhanced understanding of site conditions. In conjunction with the additional site characterization, a revised list of COPCs has also been developed, as described in Section 3.2. Data needs with respect to some of these COPCs are currently being filled. As additional data are collected at NPR, the CSM will continue to be revised, as necessary. Completion of the updated CSM was based on the assumption that petroleum hydrocarbon constituents and sulfolane are the only site COPCs (pending additional data collection for the revised COPC list).

The updated CSM was developed following ADEC's October 2010 documents including Policy Guidance on Developing Conceptual Site Models, and Human Health Conceptual Site Model Graphic and Scoping Forms. Due to the significant difference in COPC occurrence onsite (petroleum hydrocarbon constituents and sulfolane) versus offsite (sulfolane only), two separate human health CSM Graphic Forms were prepared and updated to more clearly portray and distinguish potential exposure pathways for possible onsite and offsite receptors.

The basis for selection for deselection of environmental media, exposure pathways/routes and current/future receptors for the updated CSM is described in the following sections. Please refer to the attached CSM graphic and scoping forms (Appendix P).

3.12.1 Onsite Media Selection

Surface Soil: Available data indicate that limited surface soil samples have been collected onsite. Therefore, transport mechanisms including migration to subsurface and groundwater, volatilization and runoff/erosion were selected for further evaluation. Uptake by plants or animals was not selected because the site is an active refinery and is expected to remain commercial/industrial in the future, and these potential receptors have historically been absent from the site.

Subsurface Soil: Limited data indicate that COPCs are present in onsite subsurface soil. Therefore, transport mechanisms including migration to groundwater and volatilization were selected for further evaluation. Similar to surface soil, uptake by plants or animals was not selected because the site is an active refinery and is expected to remain commercial/industrial in the future, and these potential receptors have historically been absent from the site.

Groundwater: Based on analytical results, onsite groundwater has been impacted by COPCs. Therefore, transport mechanisms including volatilization, flow to surface water body and sediment, and uptake by plants or animals were selected for further evaluation.

Air: Outdoor and indoor air and soil gas have not been evaluated. These media will be considered for further evaluation.

Surface Water: One onsite surface water sample was collected as part of 2010 site characterization activities. However, based on additional groundwater plume delineation data collected in 2010, the onsite surface water body sampled appears to be beyond the extent of the dissolved-phase plume. Additional evaluation of surface water impacts may be conducted in areas of the site that may be within the extent of the dissolved-phase plume. Therefore, transport mechanisms including; volatilization, sedimentation and uptake by plants or animals were selected for further evaluation.

Sediment and Biota: Sediment data have not been evaluated; therefore, resuspension/runoff/erosion and uptake by plants or animals transport mechanisms were selected for further evaluation.

3.12.2 Onsite Potential Receptors

Potential human receptors were identified based on current and reasonably foreseeable future land use at the site. The following potential human receptors were identified:

- Current and future commercial or industrial workers
- Current and future visitors and trespassers
- Current and future construction workers

Onsite residents were excluded due to the industrial use of the site, and because it is reasonable to assume that the site will remain in use for industrial or commercial purposes for the foreseeable future. Subsistence harvesters and consumers were not considered as receptors because the site is secured.

3.12.3 Onsite Exposure Pathways

Potential current and future onsite receptors may be exposed to constituents in surface and subsurface soils by direct contact. In general, routes of exposure by direct contact include incidental ingestion of soil, dermal contact with soil, and inhalation of constituents adhered onto dust particles that have been released by wind erosion into ambient (outdoor) air.

COPCs may leach from soil to groundwater beneath the site by percolation, resulting in potential direct contact exposures to constituents in groundwater. Ingestion of and dermal contact with COPCs in groundwater (as tap water) and inhalation of volatile COPCs released from tap water are not complete exposure pathways. Potable water is supplied to the site from a municipal source and, based on the industrial nature of the site, it is unlikely that a potable well would be installed at the site in the future. Therefore, pathways associated with potential direct contact exposures to COPCs in groundwater (as tap water) are not complete for current and potential future onsite receptors. However, depth to groundwater at portions of the site can be relatively shallow (< 6 feet). Construction/trench workers may be directly exposed to COPCs in groundwater that has pooled at the bottom of excavations. Therefore, a possible exposure pathway is dermal absorption of COPCs in groundwater by current and future construction workers.

Some COPCs identified for the site have the potential to volatilize from subsurface soil and/or groundwater into soil gas, outdoor air and indoor air. Potential exposure pathways at the site may include volatilization of COPCs in subsurface soil and/or groundwater to outdoor air and/or indoor air of current and future onsite occupational buildings, or air within a trench used by current and future onsite construction workers.

Ingestion of and dermal contact with constituents in surface water and sediment are not complete exposure pathways for onsite receptors. Although there are onsite gravel pits, it is unlikely that current and future onsite receptors would be in contact with the surface water for any significant duration of time.

Ingestion of wild or farmed foods is not a complete pathway for current or future onsite receptors. Hunting is prohibited onsite and, given the industrial nature of the site, it is not currently nor expected in the future to be used for subsistent farming.

3.12.4 Offsite Media Selection

Surface and Subsurface Soil: Only limited soil data have been collected offsite. However, there are no known offsite COPC sources associated with the site, and the only known dissolved-phase COPC that has migrated offsite is sulfolane. Sulfolane does not readily absorb to soil, so significant soil impacts from migration of impacted groundwater is not expected offsite. Therefore, surface and subsurface soil, and associated transport mechanisms and exposure pathways were not selected for further evaluation.

Groundwater: Offsite groundwater has been impacted by sulfolane. Sulfolane is not volatile, and other volatile constituents are not known to be present in offsite groundwater. Also, offsite groundwater is located at a depth greater than six feet below ground surface; therefore, uptake by root systems directly from groundwater by offsite plants is unlikely. However, impacted groundwater is known to be used for irrigation of plants and vegetables, and a garden study conducted in 2010 indicates that some plants uptake sulfolane through irrigation water. Accordingly, the transport mechanisms for groundwater selected for further evaluation include flow to private wells, surface water bodies, flow to sediment, and uptake by plants or animals.

Air: Outdoor and indoor air and soil gas have not been evaluated. Given that sulfolane is not volatile, these media will not be considered for further evaluation.

Surface Water: Surface water samples have not been collected from offsite surface water bodies located within the estimated footprint of the dissolved-phase plume. Volatile COPCs are not known to be present in the offsite dissolved-phase groundwater plume; therefore, the volatilization transport mechanism was not selected for further evaluation. Transport mechanisms selected for further evaluation include sedimentation and uptake by plants or animals.

Sediment and Biota: Sediment data have not been collected; therefore resuspension/runoff/erosion and uptake by plants or animals transport mechanisms have been selected for further evaluation.

3.12.5 Offsite Potential Receptors

Potential human receptors were identified based on current and reasonably foreseeable future land use downgradient of the site. (Note that not all pathways are significant and/or potentially complete for all receptors). The following potential human receptors were identified:

- Current and future residents
- Current and future commercial or industrial workers
- Current and future visitors, trespassers, or recreational users
- Current and future construction workers

Subsistence farmers and consumers are not identified as receptors because the site is not located in an area known for subsistence harvesting.

3.12.6 Offsite Exposure Pathways

The only known current offsite COPC is dissolved-phase sulfolane. Although dissolved-phase petroleum constituents are present onsite, the plume is undergoing ongoing active remediation, and migration appears to be controlled. Because sulfolane is not volatile and is not readily absorbable by skin, the only exposure route evaluated for potential offsite receptors is ingestion.

Ingestion of groundwater is a potentially complete pathway for the potential offsite receptors.

Ingestion of surface water is a potentially complete exposure pathway for recreational users because surface water samples within the footprint of the dissolved-phase plume have not been collected.

This pathway is incomplete for other potential receptors, because surface water in the area of the site is not known to be used as a drinking water source.

Ingestion of wild foods is a complete exposure pathway for potential offsite residents. “Wild” foods are not expected to be impacted by COPCs from the site due to the sizeable depth to groundwater and lack of offsite soil impact. However, farmed or home-grown plants irrigated with water potentially impacted by sulfolane may accumulate concentrations of this COPC. Thus, ingestion of farmed foods is a potentially complete exposure pathway for current and future offsite residents.

3.12.7 Ecological CSM

An ecological CSM to determine if COC impacts onsite or offsite will come in contact with ecological receptors is in progress. However, the optimal time for site visits to observe habitat is after spring break-up and so the final CSM could not be coordinated with the submittal of this report. Per discussions with ADEC, the ecological CSM will be developed and submitted under separate cover by June 15, 2011.

3.12.8 Risk Assessment

A risk assessment will be prepared to evaluate the risk posed by environmental conditions at the site and to develop alternate cleanup levels as appropriate. However, based on the data collected as part of the site characterization effort, some data needs are still present that are critical to a complete understanding of the conceptual site model. Section 8.0 presents recommendations to address these data needs during the 2011 field season. FHRA will meet with ADEC in June 2011 for a risk assessment Scoping Meeting. The purpose of the meeting will be to discuss preliminary CSM (as presented above), discuss the COPCs identified for the site, discuss remaining data collection needs and the plan to address them, and to discuss methodology for the risk assessment and any planned deviations from ADEC guidance. Once data collection planned for the 2011 field season has been

completed, a risk assessment work plan will be presented to the ADEC for review (estimated fourth quarter 2011). Upon approval of the work plan, a draft risk assessment will be developed and submitted to the ADEC for review and comment (estimated first quarter 2012).

3.12.9 Cleanup Levels

As noted above, data needs are still present. Once additional data have been collected, the conceptual site model will be updated and a risk assessment will be prepared. Based on the results of the risk assessment, alternate cleanup levels will be developed as appropriate. It is anticipated that a draft risk assessment will be presented to the ADEC for review and comment in first quarter 2012.

4.0 Groundwater Flow and Transport Modeling

A groundwater model of the Tanana Valley in the vicinity of the NPR has been constructed for the purpose of simulating the fate and transport of sulfolane from the site. The modeling goals were to obtain an acceptable match between the simulated versus observed water levels and sulfolane concentrations so the model can be used as a tool for assessing potential remediation options. The observed sulfolane concentrations were derived from FHRA monitoring wells. Recently received residential well sulfolane concentrations will be incorporated into future modeling efforts.

The model has been constructed using a large quantity of data of many different types from public and private sources. Approximately 2,800 unique locations have been processed and incorporated into the groundwater model. Eighty-six locations associated with the NPR, totaling ~3,500 records, were evaluated to obtain information pertaining to groundwater elevation, groundwater flow, permafrost, stratigraphy, and groundwater chemistry. USGS locations provided information pertaining to groundwater elevation and surface water data; 941 wells were used for groundwater elevation data and 29 surface water stations provided more than three million data points for surface water elevation and discharge. The ADNR WELTS database contains 1,603 locations from which permafrost, stratigraphy, and groundwater flow were interpreted. Meteorological data from three stations were evaluated for precipitation and temperature data. Digital elevation models (DEMs) were used to incorporate the ground surface and bedrock surface into the groundwater model. Finally, a variety of geographic data (e.g., soils, vegetation, land use, land survey, tax lots, roads, topography, and watersheds) were also evaluated.

The model has been developed in accordance with ADEC guidelines for fate and transport modeling (Guidance No. CSRP-98-001), including the following components:

- CSM
- Modeling program selection
- Sensitivity analysis
- Model calibration
- Model verification

- Uncertainty analysis
- Post-audit plan

The groundwater model and its various components are described extensively in Appendix Q.

Once site characterization is completed, the data will be used to update the input files for the model. The model will be updated within 90 days of the completion of site characterization tasks.

5.0 Status Update on Cleanup Actions

5.1 Onsite Remediation Results and Evaluation

The purpose of this section is to provide a summary of first quarter 2011 operating results for the existing onsite remediation system, along with an evaluation of these results. As previously discussed, ADEC and FHRA have agreed upon submittal of quarterly groundwater monitoring reports, which will include updates on remediation system performance. To satisfy this requirement, this report includes onsite remediation monitoring results for the first quarter of 2011 and follows the general reporting format discussed in the December 2010 TPT meeting. Also included in this section is an update on the implementation of the interim corrective actions described in the IRAP and in Section 9 of the SCWP. FHRA has provided ADEC with routine updates on the IRAP implementation in the TPT meetings.

Section 5.2 includes a summary of ongoing offsite efforts and describes plans for a future feasibility study to evaluate potential alternatives, including MNA, to determine how groundwater impacts beyond the limit of NPR will be addressed.

5.1.1 First Quarter 2011 Operation Summary

5.1.1.1 Groundwater Recovery

Operation of the groundwater pump and treat system currently involves groundwater recovery from four recovery wells (R-21, R-35R, R-39, and R-40), as shown on Figure 67, and a fifth recovery well (R-42) has been installed as part of the IRAP implementation. The objective of the recovery well operation is to provide capture of the shallow dissolved-phase contaminant plume. Additionally, implementation of the corrective actions described in the IRAP (as described in Section 5.1.4) include installation of a nested observation well to allow evaluation of the vertical capture of the groundwater recovery system.

Recovered groundwater is treated onsite prior to discharge and a description of the groundwater treatment system is provided in Section 5.1.2. During the first quarter of 2011, groundwater was recovered primarily from three wells (R-21, R-39, and R-40). Recovery well R-35R was online only for a short period (63 hours) prior to shutting down due to excessive sand recovery (as further discussed in Section 5.1.3). R-42 is a new recovery well installed as part of the IRAP implementation and active recovery is planned to begin in June. Startup information for R-42,

including the groundwater recovery rate and run time, will be included in the second quarter monitoring report.

Groundwater is pumped from the remediation recovery wells under water use permit LAS24907. Table 27 presents a summary of the volume and rate of recovered groundwater in the first quarter of 2011. For comparison purposes, Table 27 also includes recovered groundwater data for 2009 and 2010. The following is a summary of groundwater recovery in 2009, 2010, and the first quarter of 2011:

- 2009: 69,200,000 gallons
- 2010: 107,100,000 gallons
- 2011 (first quarter): 23,200,000 gallons

As seen in the annual groundwater recovery totals above, groundwater capture was increased significantly in 2010 as FHRA worked to optimize the existing remediation system to capture the shallow dissolved-phase sulfolane plume on the refinery property. FHRA is continuing efforts to optimize the groundwater recovery of the existing remediation system in 2011, which includes operation of the recovery wells at the maximum achievable groundwater recovery rate through piping improvements made as part of IRAP implementation. Additional IRAP improvements include operation of an added recovery well (R-42) as previously mentioned, and installation of a second prefilter as a single prefilter unit will limit future flow capacity.

5.1.1.2 LNAPL Recovery

FHRA continues to remove LNAPL from recovery wells and monitoring wells through active product pumping systems (R-21, R39, R-40, MW-138), passive product recovery canisters (S-50, S-52), and through periodic removal with a vacuum truck (R-18, R-19, R-32, R-34 and R-35 prior to failure). The recovered product is recycled within a process unit. In addition, product recovered by the groundwater recovery system is collected for recycling in a coalescer installed ahead of the air stripper. As part of the product recovery improvements described in the IRAP, FHRA is in the process of installing seven additional product recovery systems which will be installed in R-20R, R-32, R-33, R-34, R-35R (dual-phase operation), R-40 (dual-phase operation), and S-50. FHRA is also in the process of evaluating installation of a product recovery system in monitoring well O-2, which was installed as part of the site characterization process (as described in Section 2.5.1) and a LNAPL layer has been measured (as described in Section 3.7.1).

Table 28 provides a summary of LNAPL recovery at the North Pole Refinery since 1986. From 1986 to current, over 386,000 gallons of LNAPL has been recovered at the North Pole refinery. As expected, the annual product recovery volume has generally decreased as remediation has progressed and the volume of recoverable LNAPL has decreased.

In the first quarter of 2011, a total of 482 gallons of product was recovered, as shown in Table 29. The majority of this recovery was from R-21, which is a dual-phase recovery well. Evaluation of the newly expanded product recovery system performance will be included in future groundwater monitoring reports.

5.1.2 Groundwater Treatment Evaluation

As noted in Section 5.1.1, FHRA operates groundwater recovery wells to provide capture of the shallow-dissolved phase contaminant plume. The recovered groundwater is pumped to a groundwater treatment system which is operated to remove free-phase and dissolved-phase contaminants. A process flow diagram of the groundwater recovery and treatment system, including the newly installed sand filter and GAC vessels, is provided on Figure 68. The recovered groundwater discharges to a prefilter for solids removal, a coalescer for LNAPL removal, and a series of air strippers for removal of volatile organic compounds before accumulating in the Gallery Pond. The treatment system has been modified as part of the IRAP implementation to include a series of sand filters for suspended solids removal and GAC vessels for sulfolane removal; these upgrades are scheduled to be brought online in late May/early June, and startup information will be provided in the second quarter monitoring report.

5.1.2.1 Groundwater Recovery System Runtime and Pumping Rates

The section contains a summary of the recovery well runtimes for the first quarter of 2011. There were several planned downtime events during the first quarter to allow for completion of the following activities: video recording of each well screen, tie-in of new piping at R-21, tie-in of piping to R-35R, change out of the coalescer cartridge, change out of the prefilter filters, and tie-in of new prefilter piping.

R-35R was operated for a short-time in the first quarter of 2011 but was shut down due to excessive sand recovery, as further described in Section 5.1.3. FHRA has since redeveloped R-35R and installed an interior screen with a finer slot-size opening to minimize sand recovery. FHRA resumed operation of R-35R on May 11, 2011. The following is a summary of the recovery well runtimes:

First Quarter 2011 Runtime

- R-21: 2,113 hours runtime, 98% runtime
- R-35R: 63 hours runtime, 3% runtime
- R-39: 2,121 hours runtime, 98% runtime
- R-40: 2,124 hours runtime, 98% runtime

The average monthly pumping rate for the remediation system varied from 160 to 193 gpm in the first quarter (with an average of 179 gpm), as shown in Table 27. The pumping rates for the individual recovery wells are measured weekly and the average for each well is shown below.

First Quarter 2011 Average Pumping Rates

- R-21: 80 gpm
- R-35R: Off (except for 63 hours of operation)
- R-39: 77 gpm
- R-40: 32 gpm

During the first quarter, the recovery wells were pumped at reduced capacity to avoid excessive product recovery. In November 2010, the higher pumping rates resulted in increased drawdown of the water table and a subsequent introduction of LNAPL into the system. Because the coalescer was not designed to handle the higher amounts of LNAPL, dissolved-phase contaminants reached the Gallery Pond and caused an exceedance of the discharge permit limits. With the discharge piping replacement completed as part of implementation of the corrective actions presented in the IRAP, the recovered groundwater flowrate will be increased in the second quarter to maximize groundwater capture without additional risk of exceeding the discharge permit limits as any dissolved-phase hydrocarbon reaching the Gallery Pond will be removed by the GAC filters. In addition, FHRA has initiated increased efforts to monitor product recovery in the coalescer and drain more frequently (as needed), and adjust the product recovery pumps to minimize capture in the groundwater pumps.

5.1.2.2 Air Stripper Performance

The air stripper towers have effectively removed dissolved-phase hydrocarbons from the recovered groundwater prior to discharge to the Gallery Pond. The influent to the air stripper and effluent from

the Gallery Pond are sampled monthly and the results for the first quarter of 2011 are shown in Table 30. Laboratory Reports are provided in Appendix R. During the first quarter, the removal of BTEX analytes was 100% down to the laboratory reporting limit (i.e., nondetectable levels). The sulfolane removal was 51% in the first quarter of 2011. As previously noted, a GAC system has been installed to improve removal of sulfolane in the Gallery Pond effluent. The second quarter monitoring report will include a summary of the results and evaluation of the GAC effectiveness.

Additional monitoring is also scheduled to begin in the second quarter which will include collection of a laboratory sample from the air stripper effluent (prior to discharge to the Gallery Pond). This additional sample will allow evaluation of the contaminant removal occurring directly in the air stripper and any additional reduction in the Gallery Pond.

5.1.3 Summary of Nonroutine Repairs, Changes, and Maintenance

Recovery well R-35 failed in the fourth quarter of 2010 and a new recovery well was installed (R-35R). As previously mentioned, recovery well R-35R was started in the first quarter (March 7th) but only operated for 63 hours due to excessive fine-sand recovery. Additional redevelopment efforts were completed but the well continued to produce fine sand. Although a sieve analysis was used to determine the appropriate screen size during well installation, the excessive production of fine sand prompted the installation of a second interior well screen with a smaller slot size to reduce the recovery of fine sand. Groundwater recovery from R-35R was resumed on May 11, 2011. Additional startup information will be provided in the second quarter monitoring report.

The following is a list of repairs, changes, and maintenance that were conducted in the first quarter of 2011:

- 1/6/11: Downhole video recorded for R-40 to assess well and screen integrity. The video did not indicate the well screen or integrity had been compromised; however, the screen had fouling associated with biological material and precipitation. FHRA is planning to surge and clean the well screen in 2011.
- 1/31/11: Downhole video recorded for R-21 and R-39 to assess well and screen integrity. The video for both wells did not indicate the well or screen integrity had been compromised; however, the screens had fouling associated with biological material and precipitation. FHRA is planning to surge and clean the well screens in 2011.
- 2/10/11: R-21 new piping tie-in (completed as part of IRAP implementation).

- 3/3/11: Coalescer cartridge change-out.
- 3/7/11: Prefilter unit filter change-out.
- 3/10/11: Prefilter unit filter change-out.
- 3/23/11: Additional prefilter piping tie-in (completed as part of IRAP implementation).

5.1.4 IRAP Implementation Progress Update

As previously noted, FHRA has implemented interim corrective actions, as described in the IRAP, with the purpose of optimizing the existing remediation system to aggressively address, to the extent practical, LNAPL and sulfolane-contaminated groundwater on the refinery property. After a period of full-scale operation with the improvements made as part of the IRAP, the results will be evaluated as part of a feasibility study to determine if additional corrective actions are necessary to meet the objectives of LNAPL recovery and source area plume capture and treatment. The feasibility study results and additional corrective actions, if needed, will be included as part of the final remedy in the *Corrective Action Cleanup Plan*.

At the time of submittal of this report, FHRA is in the final stages of completing the interim corrective actions described in the IRAP. These corrective actions were described in detail in the IRAP and routine progress updates have been provided in the TPT meetings. Below is a list of the interim corrective actions that have been implemented with a description of any remaining tasks:

- Procured seven LNAPL recovery systems. Installation of these systems will be initiated in the second quarter of 2011. A description of the locations in which the product recovery systems will be installed is provided in Section 5.1.1.2.
- Installation of a new recovery well (R-42) to increase the width of the dissolved-phase plume capture. Active recovery at R-42 is scheduled to begin in June.
- Repaired damaged monitoring wells and observation wells.
- Replaced the discharge piping from R-21 to allow the pump to recover groundwater at a higher flowrate without transmission of solids. Although not described in the IRAP, new discharge piping was also installed to R-35R, R-39 and R-40 which will increase the overall reliability of the groundwater recovery system. The new piping was installed on pipe racks

(the replaced piping was on the ground), additional freeze protection was added, and cleanouts were added to allow future solids removal.

- Installation of three nested observation wells (MW-186A/B/C) to allow evaluation of vertical capture.
- Addition of a second prefilter prior to the coalescer to allow operation at a higher groundwater recovery rate and to allow one filter unit to be taken offline for change-out without shutting the system down. Final tie-in and active operation of the second prefilter is scheduled for June.
- Installation of a sand filter system to remove suspended solids in the Gallery Pond effluent prior to GAC filtration.
- Installation of a GAC filtration system to remove sulfolane from the Gallery Pond effluent.

As previously mentioned, FHRA is in the process of completing construction of the GAC filtration system and active operation is scheduled for late May/early June. Additional analytical monitoring is planned to monitor the sulfolane removal efficiency of the four GAC vessels, which are being operated in series. As described in the IRAP, FHRA intends to continue operating the system after sulfolane breakthrough in the fourth vessel to allow evaluation of biological growth and potential additional degradation. Future quarterly reports will provide an estimate of the carbon usage rate based on the observed sulfolane breakthrough pattern of each vessel. This data will also be compared to the ongoing testing results completed as part of the Point-of-Entry treatment system evaluation.

5.2 Offsite Feasibility Study

In accordance with Section 6.8 of the SCWP, FHRA is in the process of collecting data necessary to complete a feasibility study to evaluate potential alternatives, including MNA, to determine how groundwater impacts beyond the limits of NPR will be addressed. An additional element of the feasibility study includes further completion of flow and transport modeling efforts, as described in Section 4. The fate and transport model results, along with the conceptual site model and risk exposure pathway evaluation included as part of this report, will be the basis for evaluating future remedial alternatives including MNA. A summary of the MNA evaluation efforts underway is provided in Section 2.6.3 and initial results are provided in Section 3.9.

In the interim, to address potential drinking water risks associated with offsite dissolved-phase groundwater contamination, the following mitigation activities have been completed: (1) replacement of the City of North Pole's existing municipal wells; and (2) provision of alternate water supplies to the those residences whose private wells have exhibited detections of sulfolane.

Also, as part of the efforts to provide a long-term residential water supply, FHRA has conducted a feasibility study for in-home treatment which indicated a POE GAC filtration system as the best technology for sulfolane removal. POE treatment refers to treatment of water at the point where it enters a residence, as opposed to treatment at a centralized facility prior to distribution to individual residences. The results of the feasibility testing and recommended system design were submitted to ADEC in the *Point-of-Entry Treatment System Feasibility Study and Design Report* (Barr, 2011). FHRA has assembled full-scale POE treatment systems and conducted additional testing to evaluate effectiveness during residential usage. The following sections include a summary of results for in-home pilot testing (Section 5.2.1) and accelerated pilot testing (Section 5.2.2).

To provide assurances to residents who utilize a POE treatment system, FHRA has requested the Water Quality Association (WQA) to provide a third-party independent review as part of their Gold Seal Certification Program. WQA has completed their review of the pilot-testing results and has provided certification of the treatment system effectiveness. The WQA currently lists the certification under the name of the treatment system vendor, Richards Distributing Inc., and it will be updated to also include FHRA.

5.2.1 Point-of-Entry Treatment System In-Home Pilot Testing

The objective of the in-home pilot testing is to verify that the design basis used for the preliminary POE system design is adequate for use in final design and implementation. It is important to test the technology in full-scale (i.e., in an actual residence) on a variety of water sources to identify any variability in performance that may be due to reliability of the full-scale equipment or differences in feed-water quality. A description of the in-home pilot testing scope and monitoring plan was provided in the *Point-of-Entry Treatment System Feasibility Study and Design Report*. FHRA intends to submit an addendum to the POE report once pilot testing efforts have been completed to summarize the final results and recommendations. Prior to submittal of this addendum, a brief summary of the monitoring plan and test results is provided in this report.

FHRA is completing ongoing pilot testing in five homes that have been selected to include both higher and lower sulfolane concentrations to provide a range of anticipated water qualities. The

systems installed include a primary 2.5-cubic-foot carbon tank for sulfolane removal. FHRA has conducted weekly monitoring of the system influent (referred to as pretreatment) and primary tank effluent (posttreatment) to validate the results found in bench-scale testing and to test with actual water usage rates. Each system also contains a secondary 2.5-cubic foot carbon tank, which upon breakthrough of the first vessel, is also sampled on a weekly basis (referred to as second posttreatment).

A summary of the laboratory monitoring results through the first quarter of 2011 are provided in Tables 31A, 31B, 31C, 31D, and 31E for the five test homes (referred to as Location A, Location B, Location C, Location D, and Location E). As seen in the attached tables, the sulfolane influent (pretreatment) concentration varied from approximately 50 to 350 µg/L. In all five test homes, the POE system effectively removed sulfolane down to nondetectable levels in the primary carbon tank (posttreatment). Through the first quarter of 2011, sulfolane breakthrough from the primary carbon tank was detected in three of the five homes. The total flow volume for the three homes prior to detection of sulfolane was approximately 11,200 (Location A), 16,200 (Location C), and 27,000 (Location B) gallons. The presence of sulfolane has not been detected in any of the samples collected in the outlet of the secondary carbon tank. In the two homes in which breakthrough has not been detected, the volume of water treated (through first quarter 2011) exceeds 13,100 (Location E), and 18,300 gallons (Location D).

For the houses in which breakthrough of sulfolane has been observed in the primary vessel, the measured rate of increase in the posttreatment sample has been minimal, which indicates additional useful life of the primary carbon tank even after breakthrough. The preliminary system design described in the *Point-of-Entry Treatment System Feasibility Study and Design Report* included two primary carbon tanks operated in parallel; however, based on these results, it appears that operation of the vessel in series may extend the lifetime of the carbon effectiveness and thus reduce the frequency of the carbon changeout. FHRA has added a third polishing vessel to the homes in which breakthrough has occurred in the first vessel, so that the effectiveness of the second vessel can be monitored until breakthrough to evaluate series operation.

5.2.2 Point-of-Entry Treatment System Accelerated Pilot Testing

In addition to the in-home pilot testing, FHRA conducted two accelerated pilot tests to provide more timely information regarding sulfolane breakthrough as part of the final design process. Once again, the testing results confirmed successful sulfolane removal through a POE treatment system utilizing GAC.

The pilot tests were conducted on a full-scale system based on parallel operation with two primary 2.5-cubic-foot carbon tanks. The tests were conducted at 3 gpm through one vessel (for direct correlation of a two vessel in parallel system at 6 gpm) with different flow regimes. In the first test, the flow was constant with no downtime, while flow in the second test was a “50:50” flow scenario (20 minutes on and 20 minutes off for 16 hours, followed by eight hours of completely off). As previously mentioned, FHRA intends to submit an addendum to this report to summarize the results of these pilot-testing efforts; therefore, a brief summary of the results are provided in the remainder of this section.

For the first test conducted without downtime, the first detectable level of sulfolane in the primary tank effluent was after treatment of 10,739 gallons (Table 32). The influent concentration varied from 235 to 156 µg/L during the test.

For the second test conducted with the 50:50 flow scenario, the first detectable level of sulfolane in the primary tank effluent was after treatment of 11,794 gallons (Table 33). As seen in the in-home testing, the sulfolane concentration in the posttreatment sample showed minimal increase as the testing continued. The influent concentration during this test varied from 290 to 231 µg/L.

Based on the successful sulfolane removal demonstrated in the initial pilot testing, in-home testing, and accelerated pilot testing, FHRA is proceeding with installation of the POE systems in additional residences. As mentioned above, the purpose of the additional pilot testing was to confirm the initial pilot test results and to inform the final design process. Based on the results, the design has been modified to include operation in series (versus parallel), as this has demonstrated longer carbon lifetime which will reduce the changeout frequency, and thus reduce homeowner disturbances.

6.0 Quality Assurance/Quality Control

QA/QC procedures assist in producing data of acceptable quality and reliability. SWI reviewed the analytical results for laboratory QC samples and also conducted a QA assessment of the data as they were generated. The QA review procedures allowed SWI to document the accuracy and precision of the analytical data, as well as check that the analyses were sufficiently sensitive to detect analytes at levels below suggested action levels or regulatory standards, where such standards exist. The laboratory reports for each of the project samples for this report, including case narratives describing laboratory QA results in detail, and completed ADEC data-review checklists are included in Appendix F.

6.1 Data Review - Well Installations & Water Sample Data Quality

This section summarizes the results of SWI's QA review of data generated during the Phase 1 monitoring-well installation and sampling tasks; these assessments were provided to Reiss Remediation, LLC as monitoring-well installation and sampling progressed during the Phase 1 tasks. This section also presents Phase 2 monitoring-well installation and sampling QA/QC assessments not previously reported. The results discussed here include only the initial sample collected from each well following installation; subsequent sampling results are not presented in this section. The reader is referred to the ADEC data-review checklists presented in Appendix F for additional detail. The laboratory work orders SWI reviewed for this section are listed below.

Phase 1 water samples: 1095969, 1095975, 1096197, 1096937, 1096986, 1100933, 1100805, 1100810, 1100834, 1100852, 1100872, 1101938, and 1100900.

Phase 1 soil samples: 1100801 and 1100996

Phase 2 water samples: 1106866, 1106873, 1106876, 1106886, 1106900, 1106903, 1106910, 1106915, and 1108024.

Phase 2 soil samples: 1106717, 1106723, 1106728, 1106740, 1106753, 1106761, 1106765, 1106777, 1106791, 1106804, 1106853, 1106857, and 1106861.

6.1.1 Sample Handling

SWI hand-delivered samples to SGS at their Fairbanks sample-receiving office generally within 24 hours of collection. Samples were received there at a temperature between 0 °C and 6 °C. SGS then

shipped the samples to their Anchorage laboratory to perform the requested analyses, using the methods specified on the chain-of-custody records.

SWI reviewed COC records and laboratory-receipt forms to confirm custody was not breached and samples were kept properly chilled during shipping. The sample-cooler temperature was generally within acceptable limits upon arrival at the SGS Anchorage laboratory, with a few exceptions:

Phase 1 Sample Findings:

- The temperature blank in the cooler for SGS work order 1100810 (water) was measured below the acceptable range upon arrival at -1.0 °C; ice was noted in both bottles for sample MW-169. SWI therefore considers the result for this sample to be biased low. Ice was not noted in the other water samples, and SWI does not consider those results to be biased due to the low temperature. The initial sample from well MW-169 did not contain sulfolane at a concentration greater than the laboratory LOQ, and the low bias may have reduced a detectable concentration to a level below the LOQ.
- The cooler for SGS work order 1100805 (water) was received at the SGS office in Fairbanks within the proper temperature range, but the cooler temperature was not recorded upon its arrival at the laboratory in Anchorage. Out of an abundance of caution, SWI considers the sulfolane results for samples in this work order to be biased low, though they have no evidence to suggest the samples were received in a compromised condition. The affected samples were MW-151C (17.4 µg/L), its duplicate MW-251C (17.2 µg/L), MW-154B (not above the laboratory LOQ of 10.6 µg/L), MW-156B (113 µg/L), MW-160B (20.2 µg/L), and MW-162B (15.4 µg/L).
- The temperature of the temperature blank in the cooler for SGS work order 1100996 (soil) was 6.2 °C upon the cooler's receipt at the laboratory in Anchorage. The samples in this work order were soil samples 1489-021810-1511, 1489-021810-1512, 1489-021810-1513/1489-021810-2513, 1489-021710-1561, 1489-021710-1562, 1489-021610-1621, 1489-021610-1622, 1489-021610-1623, and 1489-021610-1624 from borings for MW-151C, MW-156B, and MW-162B. These samples did not contain sulfolane at concentrations above the LOQ. The elevated temperature (i.e., 0.2 °C above the maximum desired temperature of 6 °C) is unlikely to have affected the soil concentration of this nonvolatile analyte.

Phase 2 Water Sample Findings:

Cooler temperatures for the Phase 2 water sample delivery groups were within the acceptable range of 2 °C to 6 °C when SWI delivered them to the SGS Fairbanks receiving office in eight of the nine work orders. The temperature in one work order (11068024) was below 2 °C when SWI delivered it to the SGS Fairbanks office. USEPA publication SW-846 allows sample temperatures between 0 °C and 6 °C, and ADEC's chemist has approved sample temperatures within this range, despite the range noted on the ADEC data-review checklist. This was communicated in an e-mail between ADEC's chemist, Earl Crapps, and SGS, dated March 25, 2011.

The temperatures were below 2 °C in eight of the nine work orders upon arrival at the Anchorage laboratory. Ice was not documented in the samples associated with the below-range temperature blanks, and the reported sulfolane concentrations (whether above the LOQ or not) were unaffected in these samples. This situation was noted for the following Phase 2 work orders: 1106866, 1106873, 1106876, 1106886, 1106900, 1106903, 1108024, and 1106915.

Sample *MW-180B* from work order 1106876 was extracted and analyzed outside of hold time due to laboratory error; sulfolane was not detected in this sample but is considered biased low (flagged "JL").

Phase 2 Soil Sample Findings:

Cooler temperatures for the Phase 2 soil sample delivery groups were within the range of 2 °C to 6 °C when SWI delivered them to the Fairbanks receiving office for nine of the 13 work orders. The temperatures were below 2 °C in 12 of the 13 work orders upon arrival at the Anchorage laboratory. Ice was not documented in the associated samples and the reported sulfolane or other target analyte concentrations (whether above the LOQ or not) were unaffected in these samples. This situation was noted for the following work orders: 1106717, 1106723, 1106728, 1106753, 1106761, 1106765, 1106765, 1106777, and 1106857.

Four coolers were delivered to the SGS Fairbanks receiving office with temperatures outside the acceptable range. Work order 1106740 was received with a temperature of 6.3 °C; samples in this work order were removed from SWI's sample storage refrigerator and packed in the cooler immediately prior to delivery to SGS so the cooler temperature was unlikely to be representative of the sample temperature. Three work orders were delivered to the SGS Fairbanks receiving office with cooler temperatures below 2 °C: 1106791, 1106804, and 1106861; as noted above, the low temperatures are unlikely to have affected the target analyte concentrations in these work orders' samples.

Other than the items noted above, there were no sample-handling anomalies identified that would adversely affect data quality for this project.

6.1.2 Analytical Sensitivity

Phase 1 Sample Findings:

The reporting limits for sulfolane analyses in water ranged from 6.2 µg/L to 11.1 µg/L in the 13 Phase 1 water-sample work orders. The sulfolane reporting limits for Phase 1 soil samples ranged from 0.559 mg/kg to 0.623 mg/kg (only sulfolane was measured in the soil samples for Phase 1).

Laboratory method blanks were analyzed in association with samples collected for this project to check for contributions to the analytical results possibly attributable to laboratory-based contamination. Sulfolane was not detected in the method blanks associated with the Phase 1 work orders.

Phase 2 Water Sample Findings:

The reported LOQs for sulfolane analyses in water ranged from 10.0 µg/L to 11.4 µg/L in the nine Phase 2 water-sample work orders. Sulfolane was not detected in the method blanks associated with these work orders.

Phase 2 Soil Sample Findings:

LOQs for various VOCs and SVOCs exceeded applicable ADEC soil-cleanup levels in each of the 13 Phase 2 soil work orders. These are typically analytes that have not been detected in project samples; however, it cannot be conclusively determined whether analytes with LOQs greater than cleanup levels (where they exist) may have been present in the samples at concentrations between their cleanup levels and their LOQs.

6.1.3 Accuracy

Laboratory analytical accuracy may be assessed by evaluating the analyte recoveries from continuing calibration verification (CCV), laboratory control sample (LCS), and LCS duplicate (LCSD) analyses. LCS/LCSD samples assess the accuracy of analytical procedures by checking the ability to recover analytes added to clean aqueous or solid matrices. Accuracy may also be assessed by evaluating the recovery of analyte surrogates added to project samples.

The laboratory noted no CCV failures for this project.

Phase 1 Sample Findings:

SWI reviewed the LCS/LCSD results for the Phase 1 sample work orders to assess the analytical accuracy for these samples; the LCS and LCSD recoveries were within acceptable limits, indicating

the laboratory analyses were accurate. Each project sample reported here also had sulfolane-surrogate recoveries within QC goals. The laboratory data indicate the analytical results were accurate.

Phase 2 Water Sample Findings:

SWI reviewed the LCS/LCSD results for the Phase 2 water-sample work orders to assess the analytical accuracy for these samples; the LCS and LCSD recoveries were within acceptable limits, indicating laboratory results were accurate. Each project sample reported here also had sulfolane-surrogate recoveries within QC goals. The laboratory data indicate the Phase 2 water-sample analytical results were accurate.

Phase 2 Soil Sample Findings:

A number of LCS/LCSD analytes were above the laboratory QC limits for VOC and SVOC analyses. The laboratory often attributed these anomalies to sample dilution, and these analytes were not detected in the project samples.

A number of surrogate recoveries in the Phase 2 soil samples were outside the laboratory QC limits. Of these, many were surrogates for analytes not detected in the corresponding project samples. When a surrogate recovery outside QC limits corresponded to a project sample with an analyte concentration above the LOQ, SWI flagged the result “JH” (estimated, biased high) or “JL” (estimated, biased low).

6.1.4 Precision

SWI collected duplicate samples at a frequency of at least 10 percent of the samples submitted for organic compound analysis to evaluate the precision of analytical measurements, as well as the reproducibility of their sampling technique. To evaluate the precision of the data, SWI calculated the relative percent difference (RPD; difference between the sample and its field duplicate divided by the mean of the two); an RPD can be evaluated only if the results of the analyses for both duplicates are above the LOQ.

Phase 1 Sample Findings:

Laboratory analytical precision can also be evaluated by laboratory QC-sample RPD calculations using the LCS/LCSD and matrix spike/matrix spike duplicate (MS/MSD) results. The results of the LCS/LCSD and MS/MSD RPD calculations were within the laboratory’s acceptable range.

SWI collected 42 project samples and 11 field-duplicate samples (a total of 53 samples) for the Phase 1 water-sampling task between October 2009 and April 2010. Sulfolane was detected above the LOQ in five sample sets, and SWI was able to calculate RPDs; results of RPD calculations for these

duplicate samples ranged from 1 percent to 28 percent and were within the data-quality objective (30 percent for water) recommended by the ADEC data-review checklist for field duplicates (Appendix F). Based on their review, the Phase 1 water data reported here are considered precise.

Phase 2 Water Sample Findings:

Laboratory analytical precision can also be evaluated by laboratory QC-sample RPD calculations using the LCS/LCSD and matrix spike/matrix spike duplicate (MS/MSD) results. The results of the LCS/LCSD and MS/MSD RPD calculations were within the laboratory's acceptable range.

SWI collected 34 project samples and four field-duplicate samples (a total of 38 samples) for the Phase 2 water-sampling task. Sulfolane was detected above the LOQ in both samples in one of these pairs; hence SWI was able to calculate RPDs. The result of RPD calculation for the duplicate sample pair was 12 percent and within the data-quality objective (30 percent for water) recommended by the ADEC data-review checklist for field duplicates (Appendix F). Based on their review, the water data reported here are considered precise.

Phase 2 Soil Sample Findings:

SWI identified QC anomalies where RPDs calculated using laboratory LCS/LCSD and MS/MSD samples were outside the laboratory QC criteria in 11 of the 13 Phase 2 soil-sample work orders. In each case, SWI noted the corresponding analytes were not detected above the LOQ in the original sample.

SWI collected 58 project samples and five field-duplicate samples (for a total of 63 samples) for the Phase 2 soil-sampling task. RPDs for analytes reported above the LOQ in project sample MW-175(7.5-9) and its field duplicate MW-175D (work order 1106777) were within acceptable limits, except GRO, o-xylene, 1,3,5-trimethylbenzene, and naphthalene had RPDs greater than the ADEC data-review checklist's recommended QC target of 50 percent for soils. GRO, BTEX, sec-butylbenzene, and 4-isopropyltoluene RPDs exceeded 50 percent in project sample MW-176C (5-6.5) and its field duplicate MW-176D (work order 1106791). In project sample MW-186C (7.5-9) and field duplicate MW-186D (work order 1106853), only 2-methylnaphthalene exceeded 50 percent RPD. Project sample and field duplicate pairs 0-2(5-6.5)/0-2D and 0-2(10-11.5)/0-2DD were submitted with work order 1106861. No analytes were detected above the LOQ in sample pair 0-2(5-6.5)/0-2D. RPDs for the analytes benzene, ethylbenzene, o-xylenes, and naphthalene exceeded 50 percent in sample pair 0-2(10-11.5)/0-2DD; soil-sample heterogeneity may account for the RPDs greater than 50 percent.

6.1.5 QC Summary

By working in general accordance with the SAP, the samples SWI collected are considered to be representative of site conditions at the locations and times they were obtained. Based on their QA review, no samples were rejected as unusable due to QC failures. In general, the quality of the analytical data for this project does not appear to have been compromised by sample handling or analytical irregularities.

6.2 Data Review - First Quarter 2011 Water Sample Data Quality

This section summarizes SWI's QA review of the groundwater data collected for organic analyses (i.e., sulfolane, BTEX, and 1,2,4-trimethylbenzene) during the first quarter of 2011. The reader is referred to the ADEC data-review checklists presented in Appendix F for additional detail. The SGS work orders SWI reviewed for this section are listed below: This section summarizes SWI's QA review of the groundwater data collected for organic analyses (i.e., sulfolane, BTEX, and 1,2,4-trimethylbenzene) during the first quarter of 2011. The reader is referred to the ADEC data-review checklists presented in Appendix F for additional detail. The SGS work orders SWI reviewed for this section are as follows: 1118015, 1118024, 1118025, 1118026, 1118029, 1118035, 1118047, 1118060, 1118063, 1118067, 1118094, 1118095, 1118096, 1118101, 1118102, 1118118, 1118119, 1118129, 1118130, 1118132, 1118133, 1118144, 1118148, 1118149, 1118151, 1118152, 1118153, 1118154, and 1118162.

SWI reviewed the analytical results for laboratory QC samples and also conducted a QA assessment of the first quarter groundwater data as they were generated. The SGS laboratory reports for each of the first quarter groundwater samples, including case narratives describing laboratory QA results in detail, and completed ADEC data-review checklists are included in Appendix F.

6.2.1 Sample Handling

SWI typically hand-delivered samples to SGS at their Fairbanks sample-receiving office within 24 hours of collection. Samples were generally received there within the temperature specified on the ADEC data-review checklist (4.0 ± 2 °C). SGS then shipped the samples to their Anchorage laboratory to perform the requested analysis, using the methods specified on the chain-of-custody COC records.

Several coolers arrived in Anchorage at temperatures below the range specified on the ADEC data-review checklist, but above 0 °C. Samples associated with these colder temperatures were unaffected by the deviation from the ADEC checklist's specifications.

SWI reviewed COC records and laboratory sample-receipt forms to confirm custody was not breached and samples were kept properly chilled during shipping. The sample-cooler temperature was generally within acceptable limits upon arrival at the SGS Anchorage laboratory, with the exception of some sulfolane-analysis samples in SGS work order 1118101 (samples MW-157, MW-162A, MW-162B, and MW-151B). Those samples arrived in Anchorage containing visible ice; out of an abundance of caution, these samples' sulfolane concentrations were flagged as estimates ("J") due to the ice.

Sample holding times were met for most of the samples, with the exception of samples

MW-144B (SGS work order 1118095) and MW-169B (work order 1118144). Sulfolane was not detected in either of these samples above the LOQ. The nondetect results were flagged ("UJ") as estimated due to the hold-time exceedance.

Aside from the issues noted above, no other sample-handling problems affected the organic analyte data.

6.2.2 Analytical Sensitivity

The reporting limits for sulfolane analyses in water ranged from 10.2 µg/L to 13.7 µg/L in the 29 water-sample work orders, and were below the recommended action level for infants (25 µg/L) established by the ADEC. The BTEX and 1,2,4-trimethylbenzene reporting limits were all below ADEC groundwater-cleanup levels.

Laboratory method blanks were analyzed in association with samples collected for this project to check for laboratory-based contamination. Target organic analytes were not detected in the method blanks associated with the first quarter 2011 samples.

Trip blanks were carried during the sampling of volatile organic analytes, and were shipped with the samples to the laboratory for analysis. They were analyzed with the volatile organic samples to check for cross-contamination or contamination from outside sources during shipping and handling. No analytes were detected in the trip blanks.

Equipment blanks (EBs) were collected when non-dedicated pumps were used to collect groundwater samples, at a frequency of one EB per 20 samples. No analytes were detected in the EBs.

6.2.3 Accuracy

Laboratory analytical accuracy for these samples was assessed by evaluating the analyte recoveries from CCV, LCS, and LCSD analyses. Accuracy was also assessed by evaluating the recovery of analyte surrogates added to project samples.

The laboratory noted no CCV failures for this project. The LCS and LCSD recoveries were within acceptable limits, indicating laboratory control results were accurate.

All but one sulfolane sample (MW-239, a duplicate of sample MW-139 in SGS work order 1118094) had surrogate recoveries within laboratory QC goals. The sulfolane surrogate in sample MW-239 was recovered below laboratory control limits, so the sulfolane result for this sample was considered biased, and flagged “JL” to indicate the measured concentration was an estimate biased low. The BTEX and 1,2,4-trimethylbenzene surrogates were recovered within control limits, indicating those results were accurate.

6.2.4 Precision

SWI collected duplicate samples at a frequency of at least 10 percent of the samples submitted for organic compound analysis to evaluate the precision of analytical measurements, and the reproducibility of their sampling technique. Laboratory analytical precision was also evaluated by laboratory QC-sample RPD calculations using the LCS/LCSD and MS/MSD results.

The results of the duplicate-sample analyses were generally within the acceptable range for water-sample RPDs (i.e., less than 30 percent) with some exceptions:

- The sulfolane RPD for duplicate pair MW-143/MW-243 (SGS work order 1118162) exceeded 30 percent. The associated sulfolane results were flagged “J” due to imprecision.
- The sulfolane RPD for duplicate pair MW-139/MW-239 (SGS work order 1118094) exceeded 30 percent. The associated sulfolane results were flagged “J” due to imprecision.
- The sulfolane RPD for duplicate pair MW-113/MW-213 (SGS work order 1118094) exceeded 30 percent. The associated sulfolane results were flagged “J” due to imprecision.
- The results of the LCS/LCSD RPDs were generally within laboratory control limits, with some exceptions:

- The sulfolane RPD in work order 1118026 was outside laboratory control limits, but no associated project samples contained detectable sulfolane, so the results were unaffected.
- The sulfolane RPD in work order 1118047 was outside laboratory control limits. Samples MW-150A and its duplicate MW-250A were associated with this LCS/LCSD pair, and were flagged “J” as estimates due to imprecision.
- The sulfolane RPD in work order 1118094 was outside laboratory control limits. Samples MW-139, MW-239, and MW-101 were associated with this LCS/LCSD pair, and their sulfolane results were flagged “J” as estimates due to imprecision.
- The sulfolane RPD in work order 1118095 was outside laboratory control limits. Sample MW-144B was associated with this LCS/LCSD pair, but did not contain detectable sulfolane, so its result was unaffected.
- The sulfolane RPD in work order 1118096 was outside laboratory control limits. Sample MW-141 was associated with this LCS/LCSD pair, but did not contain detectable sulfolane, so its result was unaffected.
- The sulfolane RPD in work order 1118102 was outside laboratory control limits. Samples MW-109, MW-110, MW-130, MW-149, and MW-129 were associated with this LCS/LCSD pair, but only samples MW-110 and MW-130 contained detectable sulfolane. The sulfolane results for MW-110 and MW-130 were flagged “J” as estimates due to imprecision.
- The sulfolane RPD in work order 1118149 was outside laboratory control limits, but no associated project samples contained detectable sulfolane, so the results were unaffected.
- The sulfolane RPD in work order 1118151 was outside laboratory control limits. Samples MW-148A, MW-148B, MW-156A, MW-156B, and MW-256B were associated with this LCS/LCSD pair. The sulfolane results for these samples were flagged “J” as estimates due to imprecision.
- The sulfolane RPD in work order 1118152 was outside laboratory control limits. Samples MW-153B and MW-170C were associated with this LCS/LCSD pair. Only sample MW-153B contained detectable sulfolane, and its sulfolane result was flagged “J” as an estimate due to imprecision.

- The sulfolane RPD in work order 1118153 was outside laboratory control limits. Sample MW-149A was associated with this LCS/LCSD pair, and its sulfolane concentration was flagged “J” as an estimate due to imprecision.
- The sulfolane RPD in work order 1118154 was outside laboratory control limits. Sample MW-161A was associated with this LCS/LCSD pair, and its sulfolane concentration was flagged “J” as an estimate due to imprecision.

6.2.5 QC Summary

By working in general accordance with the SAP, the first quarter 2011 groundwater samples SWI collected for organic analysis are considered to be representative of site conditions at the locations and times they were obtained. Based on the QA review, no samples were rejected as unusable due to QC failures. Aside from the issues noted above, the quality of the analytical data for this project does not appear to have been compromised by sample handling or analytical irregularities.

6.3 Data Review - Geochemical Water Sample Data Quality

This section summarizes the results of SWI’s QA review of the geochemical-parameter data for MNA and differentiation of sub- and suprapermafrost groundwater. The reader is referred to the ADEC data-review checklists presented in Appendix F for additional detail. The SGS work orders SWI reviewed for this section are listed below.

MNA Geochemical Parameters: 1118101, 1118118, 1118129, 1118132, 1118148, 1118149, 1118151, 1118154, and 1118162.

Sub- and Suprapermafrost Geochemical Parameters: 1118147, 1118161, 1118167, 1118171, and 1118172

6.3.1 Sample Handling

SWI hand-delivered samples to SGS’s Fairbanks sample-receiving office, where they were generally received between 2 °C and 6 °C, the temperature range specified on the ADEC data-quality review checklist; for several work orders, temperature blanks were measured below this range, but above 0 °C upon delivery in Fairbanks. SGS then transferred the samples to their Anchorage laboratory by overnight carrier, where they were generally received between 0°C and 6 °C. While multiple temperature blanks were below the ADEC checklist-specified temperature range, they were within the acceptable range of 0 °C to 6 °C specified in USEPA publication SW-846 and approved by the ADEC’s chemist. The sample results are not considered to be affected by low sample-receipt

temperatures, except in the cases where ice was observed in the samples. The following samples/analyses were potentially affected by the presence of ice, and the results flagged “JL” (positive results) or “UJ” (nondetects): MW-156A – data for nitrate/nitrite and alkalinity; MW-157 – data for total organic carbon (TOC), alkalinity, total phosphorus, and total Kjeldahl nitrogen (TKN); MW-162A – data for sulfate, TOC, alkalinity, total phosphorus, TKN, total iron, and hardness; MW-162B – data for TOC, total phosphorus, and TKN; and MW-151B – data for sulfate, TOC, and alkalinity.

Other than the items noted above, there were no sample-handling anomalies identified that would adversely affect geochemical data quality.

6.3.2 Analytical Sensitivity

In multiple cases, the LOQ for total phosphorus was noted as elevated in the case narrative due to matrix interference. SGS’s LOQ for total phosphorus is typically 10.0 µg/L; the elevated LOQs were generally 100 µg/L. There is no regulatory limit for total phosphorus; this parameter is reported for purposes of evaluating MNA and to differentiate between sub- and suprapermafrost groundwater. The “elevated” LOQ does not affect data quality or usability, except one cannot determine if total phosphorus was present between the typical LOQ and the elevated LOQ.

Laboratory method blanks were analyzed in association with geochemistry samples collected for this project to check for laboratory-based contamination. Analytes were not detected above LOQs in the method blanks, with one exception. Zinc was detected above the LOQ in a method blank reported in work order 1118172; however, the zinc result for the one project sample associated with this method blank was greater than 10-times the concentration detected in the method blank. In accordance with the EPA’s National Functional Guidelines for Inorganic Data Review, the result should not be considered affected by the method-blank detection. However, the laboratory flagged the result “B.”

No trip blanks were submitted for the MNA and sub-and suprapermafrost sample work orders addressed in this section, since no volatile analyses were requested. No equipment blanks were submitted; geochemical parameters were measured for purposes of evaluating MNA and to differentiate between sub- and suprapermafrost groundwater, not as contaminants of concern. The data are usable for the purposes for which they were obtained.

6.3.3 Accuracy

Laboratory analytical accuracy was assessed by evaluating the analyte recoveries from CCV, LCS, and LCSD analyses. There were no CCV recovery failures affecting the accuracy of geochemical data, and LCS/LCSD recoveries were within laboratory control limits for each sample and analyte.

For some analyses, the laboratory analyzed an MS and MSD in addition to the LCS, to evaluate their ability to recover analytes from matrices similar to those of project samples. MS/MSD recoveries were within laboratory control limits, with the following exceptions:

- Several MS/MSD recovery failures were noted where the original sample spiked for the MS/MSD was not from the MNA or sub- and suprapermafrost project-sample set, so the results were unaffected.
- In several work orders, MS recovery of calcium was outside laboratory control limits, but the concentration in the original sample was at least 4-fold greater than the spiked amount. If spiking levels are low relative to the native analyte concentrations, it is not appropriate to flag the result; the low MS recovery therefore did not affect the result for this analyte.
- In work order 1118118, MS recovery of TKN was below laboratory control limits. The sample spiked for this MS was MW-157, and the TKN result (not-detected above the LOQ) should be considered potentially affected by the low bias, and was flagged “UJ.”
- In work order 1118167, MS recovery of sulfate was below laboratory control limits. The sample spiked for this MS was MW-162B, and the sulfate result should be considered affected by the low bias, and was flagged “JL.”

Based on CCV, LCS/LCSD, and MS/MSD recovery information, the results are considered accurate for purposes of this project, with affected data flagged as described above.

6.3.4 Precision

SWI collected duplicate samples at a frequency of at least 10 percent of the project samples collected to evaluate the precision of analytical measurements, and reproducibility of the sampling procedure. Field-duplicate RPDs, where calculable, were within data-quality objectives.

Laboratory analytical precision was also evaluated by laboratory QC-sample RPD calculations using the LCS/LCSD, MS/MSD, and laboratory duplicate-sample results. LCS/LCSD and MS/MSD RPDs were within laboratory control limits. SGS reported laboratory duplicate-sample RPD failures for

total phosphorus and/or TKN in a number of case narratives; in each case, the QC-sample pages of the report, as well as the electronic data deliverable (EDD), indicated an RPD within the laboratory control limits. It appears the duplicate-sample RPD failures were noted by the laboratory in error, and precision for these analyses is acceptable.

In some cases, the laboratory did not analyze duplicate samples, so there was no measure of analytical precision. However, field-duplicate RPDs indicated adequate overall precision; the geochemical results are sufficiently precise for purposes of evaluating MNA of sulfolane and differentiating between sub- and suprapermafrost groundwater.

6.3.5 QC Summary

By working in general accordance with the SAP, the geochemical samples SWI collected are considered to be representative of site conditions at the locations and times they were obtained. Based on this QA review, no samples were rejected as unusable due to QC failures. Sample results affected by sample-handling or QC anomalies are flagged as noted in the appropriate section; where multiple flags corresponded to a single result, the most conservative flag was used. In general, the quality of the analytical data for this project does not appear to have been compromised by sample handling or analytical irregularities, and is considered adequately sensitive, accurate, and precise for the purposes of assessing MNA of sulfolane and differentiating between sub- and suprapermafrost groundwater.

7.0 Summary and Conclusions

Site characterization is ongoing. Preliminary conclusions have been drawn from the data gathered to date and are discussed below. In some cases, however, completion of the site characterization tasks is required to confirm these conclusions. Plans to complete those tasks are described in Section 8.0. The IRAP implementation is ongoing.

7.1 Potential Sources of Contamination

Potential sources of contamination include product storage tanks; USTs; railcar-loading area; the former truck-loading rack; the process areas; the wastewater system, including the wastewater lagoons, sumps and drain systems; drum storage areas; waste piles; and septic systems (Figure 14).

A total of 3,096 documented spills have occurred from 1977 to 2010, with a total volume of approximately 282,000 gallons. Spills have occurred at numerous locations, including the process areas (CUs #1, #2, #3, and the EU), the wastewater lagoons, the tank farms, the railcar-loading rack area, and the current and former truck-rack areas (Figure 3). While files indicate that cleanup actions have occurred, for many spills, facility records contain little information regarding confirmation sampling. Therefore, a data need exists regarding the soil impacts. A soil investigation (described in Section 8.1) will be performed in 2011 to fill this data need.

Based on a review of historical documents, the primary contributors to sulfolane impacts to groundwater are likely the result of wastewater releases from sump 02/04-2 and Lagoon B. Contributions of sulfolane to the environment from discrete surface spills, including spilled fuels, appears less significant than the subsurface wastewater releases. Analysis of LNAPL samples from the wells located near the tank farms area supports this hypothesis, as sulfolane has only been detected in LNAPL collected from well MW-138, which is located near sump 02/04-2 and the EU.

The potential for ongoing releases is minimized by NPR's tank, piping and sump inspection programs, which will alert NPR staff to ongoing releases. LNAPL and groundwater monitoring results will continue to be evaluated for changing trends that would indicate a release.

7.2 Contaminants of Concern

As noted in Section 3.2, additional COPCs have been identified through review of products used at the site. An initial list of COI soil concentrations were compared with ADEC (2010) screening levels protective of potential migration to groundwater based on a zone with less than 40 inches of annual

precipitation (ADEC, 2008a; Table B1, Method Two). If ADEC soil screening levels were unavailable, then constituent concentrations in soil were compared with USEPA (2010) Regional RSLs based on potential migration to groundwater. Soil screening levels for GRO, DRO, and RRO were from ADEC (2008a) Table B2 Method Two. COI groundwater concentrations were compared with ADEC groundwater screening levels (ADEC 2008a; Table C). If ADEC groundwater screening levels were unavailable, then constituent concentrations were compared with USEPA RSLs based on tap water ingestion. Those COIs with maximum concentrations or PQLs (when all samples were nondetect) exceeding applicable ADEC screening levels were identified as COPCs.

Eight COIs do not have ADEC screening levels or USEPA RSLs, and no toxicity levels have been established by USEPA in IRIS. In order to refine the COPC list, further research will be conducted to determine if independent toxicity evaluations have been conducted for these eight COIs. Based on the research findings, the COPC list will be revised and submitted to ADEC for approval.

Additional soil sampling is planned for the NPR site (Section 8.1). Select samples collected during the planned soil assessment will be submitted for the full suite of COPCs, refined as per the research noted above. If the results of the soil analysis indicate concentrations of any of the COPCs at levels exceeding ADEC or USEPA screening levels, then a recommendation for limited groundwater sampling for the expanded COPC list will be forwarded to ADEC. It is anticipated that the initial groundwater sampling, if necessary, will include the same list of wells that are included in the BTEX monitoring program. Based on the initial groundwater results, additional wells will be added to the program as appropriate. If detectable concentrations in soil for COPCs with no ADEC or USEPA screening level are observed, then ADEC will be contacted to determine appropriate groundwater sampling.

7.3 Geology

NPR and the area surrounding North Pole is located on the Tanana River Floodplain. The geology of the area is dominated by a thick sequence of unconsolidated alluvial deposits up to 600 feet thick. Discontinuous layers of silt, fine sandy silt, and silty fine sand, with occasional peat lenses, have been encountered in the upper 10 feet of the unconsolidated sequence. Alluvial sand and gravel characterized as sandy gravels and gravelly sands, with occasional discontinuous lenses of sand, silt, and organic deposits, are present below the silty layers.

The GPR survey indicated the presence of silty layers in the shallow subsurface in onsite areas that had not been identified through traditional drilling means. Onsite these layers would likely influence

the migration of contaminants in the vadose zone and shallow saturated zone, and may also influence onsite cleanup efforts. Data gathered during the planned soil investigation (described in Section 8.1) will fill this data need.

7.4 Permafrost

Permafrost has been delineated using data from monitoring wells and private wells installation logs and the data have been used in the construction of the groundwater model.

Top-of-permafrost depths ranged from six feet to 150.5 feet BGS in the study area. Residential well logs indicate that the bottom of the permafrost ranges from 14 to 245 feet BGS and that the thickness of permafrost layer ranges from five feet to 232 feet. Moving northwest from NPR, it appears that the top of permafrost becomes shallower. The upper surface of the permafrost appears to be deepest near NPR, and also near Badger Slough. A “valley” in the upper surface of the permafrost appears to extend northwest from NPR along Old Richardson Highway the Alaska Railroad.

Permafrost will continue to be logged as it is encountered during future subsurface investigations.

7.5 Hydrogeology

Reference values of hydraulic conductivities of the aquifer materials range from eight to 2,400 ft/day. Hydraulic conductivity estimates based on grain-size range from 1.1 to 1,600 ft/day. Aquifer testing at NPR indicated a hydraulic conductivity of approximately 130 ft/day for wells screened in the upper 15 feet of the aquifer. Aquifer testing of the City’s new water supply wells indicated a hydraulic conductivity ranging from approximately 700 to 1,100 ft/day based on pumping of wells screened from approximately 120 to 150 feet below the water table. Pumping data from new onsite recovery wells will be used to refine these estimates.

The water table in the area is shallow, typically occurring within 15 feet of the ground surface (480 to 490 feet MSL onsite and 460 to 485 feet MSL offsite), and usually within the alluvial sand and gravel, and occasionally in the silty deposits. The water table decreases in elevation from southeast to northwest, mimicking the gradually decreasing elevation of the ground surface.

Based on limited data, the water table has fluctuated vertically up to four feet since 2007 (Appendix N). Seasonal lows typically occur any time from late March through May, with seasonal highs occurring in July or August.

Groundwater flow directions are controlled by discharge from the Tanana River to the aquifer and from the aquifer to Chena River. Variations in river stage are believed to be the primary cause of variations in flow direction. USGS data indicate that flow direction varies up to 19°, from a north-northwesterly direction to a few degrees east of north. The flow direction trends to the north-northwest in spring and more northerly in the summer and fall. Data collected thus far confirm that flow direction does vary, although the limited data set does not fully capture the 19° variation. A gradient of 5.5 feet per mile and a groundwater velocity of approximately 1.3 ft/day have been calculated.

The limited data set has indicated an upward vertical gradient at all but one well nest (MW-151).

Collection of groundwater elevation data through manual and automated means will continue as described in Section 8.2.

7.6 Soil Impacts

Due to the limited nature of previous soil investigations across NPR, data needs exist in the understanding of onsite soil impacts. Soil samples with COC concentrations exceeding SCLs have been reported at several locations across the site, and the extent of these impacts has not been determined. The soil investigation described in Section 8.1 will be utilized to fill this data need.

7.7 Laboratory Drain

Laboratory analysis of the soil samples collected during the laboratory drain investigation indicated constituents of COCs exceeding the applicable ADEC standards in the soil samples collected from SBLAB-4. Boring SBLAB-4 was installed near the high-use sink in the hydrocarbons laboratory on the north end of the building. Soil samples from the 1.6 to 1.8-foot interval and the 3.8 to 4.0-foot interval exhibited concentrations of TPH-D that exceed the applicable standard of 250 mg/kg. In addition, the shallower sample (1.6 to 1.8 feet) also exhibited concentrations of 2-methylnaphthalene that exceed the standard of 6.1 mg/kg, but the concentration in the deeper sample (3.8 to 4.0 feet) was nondetectable.

Arsenic was detected in each of the eleven soil samples collected during the laboratory investigation, and was present at concentrations exceeding the applicable ADEC standard of 3.9 mg/kg in both of the samples collected from SBLAB-1 (3.0 to 3.2 feet and 5.2 to 5.4 feet). However, the concentrations detected in these samples (4.92 mg/kg and 4.13 mg/kg, respectively) do not exceed a site-specific background concentration in soil of 14.46 mg/kg, as reported by SWI (2001) and

developed by the Alaska District USCOE based on soil data collected in the area of Fort Wainwright, Alaska.

Sulfolane was not present at detectable concentrations in any of the soil samples selected for laboratory analysis. The detection limits for these samples ranged from 0.495 mg/kg to 0.525 mg/kg. The cleanup level for sulfolane in soil, established by ADEC in the January 2006 approval of the CAP is 0.943 mg/kg for migration to groundwater.

Although concentrations of TPH-D were detected above the applicable ADEC standard in the soil samples collected from one boring, the concentrations decreased with depth, and are only slightly above the cleanup standard in the deeper sample. Additional soil assessment in this area is not warranted at this time. Additional soil sampling to assess general conditions at NPR is discussed in Sections 8.3 and 8.4. Furthermore, the laboratory is located upgradient of multiple wells that are included in the quarterly groundwater monitoring program, and so installation of additional groundwater monitoring points to assess conditions around the laboratory is also not proposed at this time.

7.8 LNAPL

LNAPL was generally present in the same areas in which it had been reported previously, with the exception that it was observed in new observation well O-2, which is located north of containment area CA4. Installation of a well in this area is discussed in Section 8.3.

At most locations, LNAPL thicknesses increase as the water table elevation decreases. To date, a full annual cycle of data has not been collected from the expanded LNAPL monitoring network. These data are important to understand the LNAPL occurrence and recoverability. LNAPL monitoring will continue as described in Section 8.3.

Bail-down testing conducted thus far provided a preliminary indication of the recoverability of LNAPL in the vicinity of the remediation system. Additional bail-down testing will be completed, as described in Section 8.3, to further characterize recoverability of LNAPL at the site.

LNAPL occurrence and recoverability may be influenced by geologic features such as silty layers in the vadose zone and the shallow saturated zone. The continuous soil sampling to be completed as part of the shallow soil investigation, described below in Section 8.1, will provide the data necessary to map these potential fine-grained layers.

Smear zone LNAPL is apparent in the vicinity of well O-2, but not O-1. The composition of LNAPL in the smear zone at O-2 was similar to that of LNAPL collected at nearby S-33. A smear zone LNAPL is not present in the vicinity of O-3 or O-4. Additional soil samples for smear zone analyses will be collected during the soil investigation described in Section 8.1.

To date, sulfolane has been detected only in the LNAPL sample collected from MW-138. This would suggest that LNAPL is not a primary source of sulfolane in the groundwater. Additional LNAPL analyses will continue as described in Section 8.3.

Development of the LNAPL conceptual model will continue as the tasks described in Section 8.3 are completed.

Deep monitoring well data indicate that DNAPL is not present, as suspected due to the miscibility of sulfolane in water.

7.9 Groundwater Impacts

7.9.1 BTEX & 1,2,4-TMB

The benzene plume appears relatively well defined as an onsite plume, and the toluene, ethylbenzene, and xylenes plumes appear to be located within the footprint of the benzene plume. While the benzene concentrations in samples from several wells were reported to exceed the ADEC groundwater cleanup level, toluene exceeded its respective cleanup level at only two wells. All reported ethylbenzene and total xylenes concentrations were below ADEC cleanup levels.

Thus far, all wells with 1,2,4-TMB detections are located within the benzene plume, and none of the reported concentrations exceed the ADEC cleanup level for 1,2,4-TMB.

Statistical evaluation indicated stable or decreasing BTEX trends at most locations, which would indicate that the BTEX plumes have stabilized and are not migrating offsite. It is also an indication that no new releases of petroleum products have impacted groundwater. Increasing trends were indicated at a few wells; however, further evaluation of the analytical data revealed fluctuating concentrations potentially influenced by seasonal fluctuations in the water table. The potential relationship between BTEX concentrations and groundwater elevations has yet to be established.

Insufficient data have been collected to establish 1,2,4-TMB trends at any locations. Trends for BTEX have not been established at wells recently added to the monitoring network. Continuation of monitoring for BTEX and 1,2,4-TMB is described in Section 8.4.

7.9.2 Sulfolane

Numerous wells have been installed onsite and offsite to delineate the sulfolane plume horizontally and vertically. A few data needs exist along the edges of the plume; therefore, FHRA will install six monitoring wells across the water table and eight to a depth of approximately 50 feet BGS, as described in Section 8.5. In deeper intervals, permafrost appears to be present north and west of NPR, and the plume appears to be defined horizontally and vertically in the unfrozen aquifer.

Little variation has been observed in the footprint of the plume, an indication that the plume overall is stable. Statistical analysis of sulfolane data indicates decreasing or stable trends at most locations, further indication that the plume is stable. Increasing trends were indicated at MW-142 and MW-161A. Further evaluation of the MW-142 data indicates a fluctuating concentration, possibly related to groundwater elevation changes. MW-161A is located approximately 9,000 feet downgradient of NPR, and none of the wells between MW-161A and NPR have increasing trends. Monitoring of the sulfolane network will continue as described in Section 8.5.

Sulfolane has been detected at concentrations above the interim cleanup goal in 132 private wells. FHRA is providing alternate drinking water supplies to residents with known impacted private wells.

According to well installation logs, a few private wells with sulfolane detections are screened below permafrost. Geochemical evaluations of the groundwater from these wells suggest that the composition of sulfolane-impacted water collected from subpermafrost wells may be similar to other unimpacted subpermafrost water. However, the data are insufficient to confirm any hypotheses regarding the flow path of the sulfolane to this subpermafrost zone. Additional chemical analyses are being considered and will be discussed with ADEC upon determination of a proposed path forward.

7.9.3 MNA Evaluation

MNA data collected to date were limited to a single partial round of sampling. In accordance with the SCWP, the MNA analysis will be updated as additional data become available. Preliminary multivariate data analyses show that sulfolane concentrations are negatively correlated with dissolved oxygen concentrations, possibly indicative of aerobic sulfolane degradation. Positive correlation had been noted between sulfolane concentration and pH, an indication of biological sulfolane oxidation. Sulfate, the aerobic degradation product of sulfolane, does not correlate with sulfolane concentration, although changes in sulfate concentration may be difficult to detect due to high background sulfate concentrations.

Isotherm testing results indicate that the degree of sulfolane adsorption to aquifer sediment is anticipated to be similar to what has been published in the literature for other sites. The distribution coefficients calculated from this work will be used to estimate the mass of sulfolane adsorbed to sediment, and account for that mass when assessing MNA progress. Continuation of MNA monitoring in support of the upcoming Offsite Feasibility Study is described in Section 8.6.

7.10 Gravel Pit and Surface Water

Sulfolane has not been detected in water samples collected from the onsite gravel pits and Badger Slough, indicating that the shallow plume does not discharge to these features. No further sampling is planned at this time.

7.11 Updated CSM

7.11.1 Onsite

Potential current and future onsite receptors may be exposed to constituents in surface and subsurface soils by direct contact including incidental ingestion of soil, dermal contact with soil, and inhalation of constituents adhered onto dust particles that have been released by wind erosion into ambient (outdoor) air. Data to be gathered during the upcoming soil investigation will further define the areas of soil with COPCs present, as described in Section 8.1.

COPCs may leach from soil to groundwater beneath the site by percolation resulting in potential direct contact exposures to constituents in groundwater. Due to the shallow nature of groundwater at the site, construction/trench workers may be directly exposed to COPCs in groundwater that has pooled at the bottom of excavations. Therefore, a possible exposure pathway is dermal absorption of COPCs in groundwater by current and future construction workers. Cleanup actions related to onsite groundwater impacts are underway, as described in Section 5.

Some COPCs identified for the site have the potential to volatilize from subsurface soil and/or groundwater into soil gas, outdoor air and indoor air. Potential exposure pathways at the site may include volatilization of COPCs in subsurface soil and/or groundwater to outdoor air and/or indoor air of current and future onsite occupational buildings, or air within a trench used by current and future onsite construction workers. Data to be gathered during the upcoming soil investigation will further characterize soils which may contain volatile COPCs, as described in Section 8.1. Cleanup actions related to onsite groundwater impacts that may produce soil gas are underway, as described in Section 5.

7.11.2 Offsite

The only known current offsite COPC is dissolved-phase sulfolane. Because sulfolane is not volatile and is not readily absorbable by skin, the only exposure route evaluated for potential offsite receptors is ingestion. Ingestion of groundwater is a potentially complete pathway for the potential offsite receptors. FHRA is providing clean drinking water sources to the owners of private wells that have sulfolane present at concentrations that exceed the laboratory reporting limit of 10 ppb. Further characterization of the offsite sulfolane plume and the continuation of the MNA evaluation in support of the upcoming Offsite Feasibility Study are described in Section 8.6. Following completion of site characterization, groundwater fate and transport modeling will be completed to predict the behavior of the offsite sulfolane plume.

Ingestion of surface water is a potentially complete exposure pathway for recreational users because surface water samples within the footprint of the dissolved-phase plume have not been collected. This pathway is incomplete for other potential receptors, because surface water in the area of the site is not known to be used as a drinking water source.

Ingestion of wild foods is not a potentially complete exposure pathway for offsite residents. Wild foods are not expected to be impacted by COPCs from the site due to the sizeable depth to groundwater and lack of offsite soil impact. However, farmed or home-grown plants irrigated with water potentially impacted by sulfolane may accumulate concentrations of this COPC. Thus, ingestion of farmed foods is a potentially complete exposure pathway for current and future offsite residents. Results of a limited garden study, which was conducted to evaluate sulfolane uptake by home-grown plants was prepared by the Alaska Department of Health and Social Services.

7.11.3 Ecological CSM

The ecological CSM is in progress and will be developed and submitted under separate cover, as described in Section 8.7.

7.12 Cleanup Actions

7.12.1 Groundwater Recovery

Optimization of the existing pump and treat remediation system resulted in a significant increase in captured impacted groundwater onsite from 69,200,000 gallons in 2009 to 107,100,000 gallons in 2010. Additional optimization efforts being made in 2011 include improvements to the recovery well discharge piping (part of IRAP implementation) to allow operation of the recovery wells at their maximum achievable groundwater recovery rates. During the first quarter of 2011, 23,200,000

gallons of groundwater were recovered. A new recovery well (R-42) is being added to the system to increase horizontal and vertical capture of impacted groundwater.

7.12.2 LNAPL Recovery

From 1986 through the first quarter of 2011, over 386,000 gallons of LNAPL have been recovered at the North Pole refinery. Annual recovery volumes have generally decreased as remediation has progressed and the volume of recoverable LNAPL has decreased. Four hundred eighty-two gallons of LNAPL were recovered in the first quarter of 2011. Recovered LNAPL is recycled within a process unit at NPR.

As part of the IRAP, seven additional product recovery systems are being installed in R-20R, R-32, R-33, R-34, R-35R (dual-phase operation), R-40 (dual-phase operation), and S-50. FHRA is also evaluating installation of a product recovery system in monitoring well O-2.

7.12.3 Groundwater Treatment

The recovered groundwater is pumped to a treatment system that removes LNAPL and dissolved-phase contaminants. The recovered groundwater discharges to a prefilter for solids removal, a coalescer for LNAPL removal, and a series of air strippers for removal of VOCs before accumulating in the Gallery Pond. Although they were not operating in the first quarter of 2011, the treatment system has been modified as part of the IRAP implementation to include a series of sand filters for suspended solids removal and GAC vessels for sulfolane removal.

7.12.4 IRAP Progress and Onsite Feasibility Study

FHRA is completing interim removal actions in accordance with the IRAP to aggressively address onsite LNAPL and contaminated groundwater. After a period of full-scale operation with the improvements made as part of the IRAP, the results will be evaluated as part of an Onsite Feasibility Study to determine if additional corrective actions are necessary to meet the objective of LNAPL recovery and source area plume capture and treatment. The feasibility study results and additional corrective actions, if needed, will be included as part of the final remedy in the *Corrective Action Cleanup Plan*.

7.12.5 Offsite Feasibility Study

FHRA is in the process of collecting data necessary to complete a feasibility study to evaluate potential alternatives with respect to the offsite plume. One element of the feasibility study includes completion of fate and transport modeling efforts, as described in Section 4. The fate and transport

model results, along with the updated CSM included in this report, will be the basis for evaluating future offsite remedial alternatives, including MNA.

In the interim, to address potential drinking water risks associated with the offsite plume, the City's municipal wells have been replaced and alternate drinking water have been provided to residents with known impacted private wells.

FHRA has conducted a feasibility study for in-home treatment of sulfolane-impacted groundwater, which indicated that POE GAC filtration is the best technology for sulfolane removal. FHRA has assembled full-scale POE treatment systems and conducted additional testing to evaluate effectiveness during residential usage.

To provide assurances to residents who utilize a POE treatment system, FHRA enlisted WQA to provide a third-party independent review as part of their Gold Seal Certification Program.

8.0 Recommendations

As stated in Section 7.0, preliminary conclusions have been drawn from the data gathered to date; however, in some cases, the completion of the site characterization tasks are required to confirm these conclusions. Tasks to be completed and new tasks that are needed to fill data needs are described below.

8.1 Soil Investigation

FHRA is proposing to complete an onsite soil investigation. Soil borings will be completed in a grid across the site. The gridlines will be spaced at 100-foot intervals and borings will be placed at the intersections of the gridlines to the extent practical, within accessible areas of the property. Goals of the investigation will be:

- Delineate silty layers in the shallow subsurface;
- Investigate known and potential releases by characterizing soil impacts at boring locations;
- Confirm the presence or absence of sulfolane in the release locations;
- Determine the presence of COPCs in soils; and
- Provide additional soil samples for smear zone chemical profiling to fill data needs for the LNAPL conceptual model.

No clearing of woods or brush will occur, and no borings will be placed in lined containment areas. Boring locations may be moved within the grid to avoid utilities, trees, or other structures which may prevent the safe installation of the borings. The borings will be advanced using the direct-push or similar technique and soil samples will be collected continuously for classification, field screening, and potential laboratory analysis. Soil classification and field screening will be completed in accordance with the SAP. Soil borings will be advanced to a depth that is sufficient to delineate the vertical extent of contamination based on field screening (within the limits of the drilling technology) or the water table, whichever is deeper. Soil samples will be analyzed for the current list of COPCs. A methodology for selecting soil samples for laboratory analysis will be described in a work plan to be prepared for ADEC review. The work plan will provide additional specific details of the soil investigation and any necessary updates to the SAP.

Data from the soil investigation will be tabulated and evaluated with data from the laboratory drain investigation, the sump investigation, and the site characterization.

Based on the results of the soil investigation, these COPCs will be considered for groundwater monitoring at onsite wells.

8.2 Groundwater Elevation Monitoring

Groundwater elevation monitoring has begun, and will continue not only as site characterization continues, but also as part of any future long-term groundwater monitoring. To date, a full annual cycle, necessary to gauge seasonal variations in gradient and flow direction, has yet to be collected from the expanded monitoring network, including the well nests. These data will be used to further characterize horizontal and vertical gradients, and will be important for the ongoing and future onsite cleanup actions and the feasibility study. All new wells installed since submittal of the SCWP, and to be installed during 2011, will be added to the monitoring network. An updated summary of the locations in the network is shown in Table 34. Automated measurements will also continue at the wells in which pressure transducers and data loggers are installed.

Potential influences of permafrost on groundwater flow will be evaluated as data are collected. Permafrost has been delineated to the extent practical using data from monitoring wells and private wells installation logs, and the data have been used in the construction of the groundwater model.

8.3 LNAPL Investigation

LNAPL monitoring has begun, and will continue through site characterization and long-term groundwater monitoring. To date, a full annual cycle has yet to be collected from the expanded LNAPL monitoring network. These data are important to understand the LNAPL occurrence and recoverability. Therefore, FHRA will continue to execute the plan proposed in the SCWP, with the following additions. The new observation wells O-1, O-2, O-3, and O-4, and new water table wells MW-176A, MW-178A, MW-179A, and MW-180A, will be added to the LNAPL monitoring network (Table 34).

Due to the presence of 0.55 feet LNAPL in well O-2, product recovery was initiated. A product recovery system will be installed in the well to provide continuous removal of product and to prevent potential migration of product in the area of this well. FHRA proposes to install an additional observation well approximately 150 feet northwest of O-2 to confirm product recovery from this well is effective. The proposed location of the well is shown on Figure 69. The well will be installed in

accordance with the techniques and methods described in the SCWP and SAP and will be added to the LNAPL monitoring network, as shown in Table 34.

Bail-down testing indicated potential good recoverability of LNAPL for most of the wells tested to date. Additional bail-down testing is proposed to provide a more comprehensive indication of recoverability across the site, along with calculations of LNAPL transmissivity from the resulting bail-down data. LNAPL transmissivity is a parameter that can be compared to published benchmarks, and tracked as a measure of remedial progress. Bail-down testing will be completed semiannually at the wells listed in Table 35.

LNAPL occurrence and recoverability may be influenced by geologic features such as silty layers in the vadose zone, the capillary fringe, and the shallow saturated zone. The continuous soil sampling to be completed as part of the shallow soil investigation, described above in Section 8.1, will provide the data necessary to map these potential fine-grained layers.

The limited number of smear zone samples provided an initial indication that LNAPL impacts are generally shallow. Additional smear-zone sampling is proposed to provide a more comprehensive indication of smear zone thickness across the site. This sampling will be completed during the soil investigation described in Section 8.1. Specific locations to complete the smear zone profiling will be described in the soil investigation work plan.

Sampling of LNAPL indicated variability in physical characteristics, composition, and sulfolane content across the site. Additional LNAPL composition sampling is proposed to provide a more comprehensive understanding of LNAPL characteristics across the site and provide input for further development of the LNAPL conceptual model. Additionally, it is proposed to measure LNAPL viscosity at groundwater temperature rather than 60°F, as this would be more representative of in-situ viscosity. FHRA proposes to collect LNAPL samples for laboratory analysis from wells O-1, O-2, and R-14, if it is present. Analyses will be completed in accordance with the modified methods described in Section 2.5.4 of this report.

8.4 Monitoring BTEX & 1,2,4-TMB in Groundwater

Most of the BTEX plume has been defined. One area that lacks clear definition is the area downgradient of the CUs. Therefore, FHRA proposes to add water table monitoring wells MW-176A, MW-179A, and MW-180A to the BTEX & 1,2,4-TMB monitoring network to provide additional plume definition in this area (Figure 70).

Insufficient data have been collected to establish 1,2,4-TMB trends at any locations, and BTEX trends at locations recently added to the monitoring network. Therefore, FHRA will continue the monitoring proposed in the SCWP, with the exception that monitoring events will be completed earlier in each quarter to allow sufficient time to complete sampling. The revised BTEX & 1,2,4-TMB monitoring network is summarized in Table 36. Data evaluation and comparison to groundwater elevation results will continue in accordance with the SCWP.

8.5 Monitoring Sulfolane in Groundwater

Horizontal and vertical delineation of the sulfolane plume has progressed; however, a few data needs exist along the plume edges. On March 8, 2011, FHRA proposed to install fourteen additional monitoring wells to progress the understanding of the sulfolane plume. Six of these wells will be installed across the water table, as shown on Figure 71. Eight wells will be installed to a depth of approximately 50 feet BGS, (within the 10 to 55 feet below the water table interval), as shown on Figure 72. No additional wells are proposed in the 55 to 90 feet below the water table interval, or the 90 to 160 feet below the water table intervals at this time (Figure 72 and 73)..

In addition, FHRA proposes to add monitoring wells MW-186A, MW-186B, and MW-186C, installed in October 2010, to the network to monitor the effects of new recovery well R-42 on groundwater.

As is the case with BTEX & 1,2,4-TMB monitoring, dissolved-phase sulfolane monitoring has just started for many of the locations in the expanded monitoring network and trends have yet to be established, especially as related to fluctuations in groundwater elevations and gradients. FHRA will, therefore, continue the sulfolane groundwater monitoring program established in the SCWP to monitor plume stability. Quarterly monitoring events, however, will be started earlier each quarter to allow sufficient time to complete each event. The revised sulfolane monitoring network is summarized in Table 37. Data evaluation and comparison to groundwater elevation results will continue in accordance with the SCWP.

8.6 Monitored Natural Attenuation

To date, one round of MNA data have been collected. MNA sampling and analysis will continue as proposed in the SCWP and in support of an upcoming Offsite Feasibility Study. As ongoing MNA data are collected, they will be evaluated for trends in the MNA parameters along the flow path, with depth and with time. When sufficient data have been collected, the Mann-Kendall trend test will be

applied to the data to discern increasing or decreasing trends in the data with distance and time (subject to any constraints of the method relative to seasonal variability).

The degree of sulfolane adsorption to aquifer sediment is anticipated to be similar to what has been published in the literature for other sites. As ongoing data collection and evaluation of MNA proceeds, the distribution coefficients estimated from this work will be used to estimate the mass of sulfolane adsorbed to sediment, and account for that mass when assessing MNA progress.

Groundwater sampling and laboratory analysis in support of the MNA evaluation will continue as described in the SCWP.

8.7 Evaluation of Subpermafrost Private Wells

The results of the geochemical sampling and analysis conducted on sub and suprapermafrost wells did not support the development of conclusions regarding the source of subpermafrost sulfolane impacts. Additional sampling and analysis will be completed to provide additional information for development of a conclusive answer regarding the source of subpermafrost sulfolane. Plans for additional sampling and new analytical methods/approaches will be detailed in a future work plan.

8.8 Ecological CSM

The ecological CSM is in progress. Results will be used to determine if COC impacts onsite or offsite will come in contact with ecological receptors. Per discussions with ADEC, the ecological CSM will be developed and submitted under separate cover by June 15, 2011.

8.9 Flow and Transport Model

Once site characterization is completed, the data will be used to update the input files for the groundwater model. The model will be updated within 90 days of the completion of site characterization tasks.

8.10 Schedule

Site characterization tasks are still ongoing, even with the preparation of this document, and will continue through 2011. The additional tasks listed above will be completed concurrently with the ongoing tasks, with the goal of completion in 2011.

8.11 Reporting

Results of the continuing site characterization tasks and the new tasks proposed here will be presented in a Site Characterization Addendum. Site characterization is anticipated to be completed

by the end of 2011. The Site Characterization Addendum will be completed approximately 90 days following the completion of site characterization.

As agreed upon with ADEC, FHRA will report the results of groundwater monitoring on a quarterly basis. Each quarterly report will be submitted at the end of the month that follows the end of the preceding quarter (e.g., the second quarter report will be submitted by July 31st).

The TPT meetings and the Site Characterization and Remediation subgroup meetings will also be used as opportunities to provide updates, propose changes to work, and discuss results.

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